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Astronomy

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ETX-90EC — $595
ETX-125EC — $895

Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

New Fork Mount Designs with Standard-Equipment Dual-Axis Drive Systems: Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

Pushbutton Electronic Hand Controller: Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

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Plus the features that created the ETX revolution:

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

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COMPUTER CONTROL
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FOCUS
OUT
SPEED
MODE
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Meade **ETX-90EC: $595** and **ETX-125EC: $895.** Each complete as shown, with electronic hand controller; plus packing and shipping.

SPECIFICATIONS: ETX-90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

OPTIONAL SYSTEMS*

#497 Autostar Computer Controller (90, 125)	$149
#880 Equatorial Table Tripod (90)	29.95
#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
#825 8 x 25mm Right-Angle Viewfinder (90)	49.95
#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
#932 45° Erecting Prism (90, 125)	49.95
#64 Photo Adapter (90, 125)	34.95
Electric Focuser #1244 (90) *or* #1247 (125)	119.95

**see the Meade accessory ad in this issue.*

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FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

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Orders: 800-767-9576; Info.: 925-447-9570.

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POCONO MOUNTAIN OPTICS, Moscow, PA.
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RIVERS CAMERA, Dover, NH.
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SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location ...only *$149!*

ETX AUTOSTAR
RA = 08:04.6
Dec = +36°38
MEADE
ENTER
MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?

The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

Digital readouts of telescope position (continuously in R.A. and Dec.), menu options, glossary, and utility functions.

Precise sidereal-rate tracking in either altazimuth or equatorial modes. For altazimuth tracking, set the telescope on its drive base and perform a quick, easy alignment.

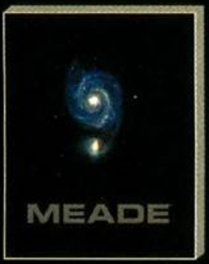
9-Speed Dual-Axis Operation: Pushbutton operation of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec.

RS-232 Serial Port: For operation of the telescope through a personal computer, using Meade Epoch 2000® sky software or other sky software using the LX200 protocol.

Plus: over 20 other menu options, including guided tours, major event menus, user-defined terrestrial objects, and much more.

MEADE
COMPUTER CONTROL

(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.



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Prices shown are suggested U.S. mail-order retail prices.
Patents pending on ETX-90EC, ETX-125EC, and Autostar.

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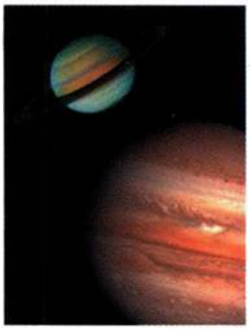

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BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Red Light Parties

Star parties may be one of the oddest and most unexpected of amateur astronomers' activities. Many readers have missed their excitement, which is a shame, because those least likely to go to star parties — armchair astronomers and beginners — are probably the ones who would gain the most from them. They'd hear great speakers and be invited to test every kind of telescope.

I think of astronomy as the ultimate solitary hobby. Most amateurs spend a great deal of time alone in a field or park or in their backyard, eye stuck to eyepiece, roaming the sky. But, like every other human endeavor, astronomy serves as an excuse for people to band together and form clubs. They want to share information, seek guidance, or simply try to shed some of the isolation associated with stargazing. Clubs loan equipment and books; they invite witty speakers to entertain them. (See "Less is More," page 86.) Sometimes, a club will buy land in the desert or the swamp so members can set up their telescopes together under dark skies (hoping that the night light of development will stay out of their site forever).

And clubs no doubt invented star parties — which are really just camp outs with telescopes and lots of nocturnal activity. Most star party guests sleep all day and stay up as late as they can, hoping to get a look at every star and galaxy that shows itself. They chat, share stories of great sky objects they've seen, the best clear skies, the biggest telscopes, the fanciest gizmos. Some share homemade telescopes and other gadgets.

Organizers look for sites with dark skies and good camping space. Sometimes the point is to draw very sophisticated amateurs with huge telescopes and acres of knowledge, as at the Texas Star Party. Sometimes the point is to show off homemade telescopes, as at the Riverside Telescope Makers Conference. Sometimes the point is to sell or trade equipment. Many of these parties seem the most grassroot of all grassroot traditions, but as they've grown popular, telescope dealers and manufacturers see them as a place to introduce people to new products. The gatherings are reasonably disorganized and relatively rule-free. (Except that the lights must be off or red.)

Some star parties, such as Stellafane, have outlawed commerce. Some embrace it. These days, national parks, planetariums, and observatories are also sponsoring shorter, more-public skywatching parties, intended to introduce newcomers to the stars.

As I write this column, we are in the high party season. Terry Conley, our calendar editor, is struggling to fit everything into her column this month as she has been since May. Two of our editors are out of the office for Universe in Toronto. Rex Graham is headed for Nebraska and Andrea Gianopoulos is soon off to Canada again. Every one of us will be out there during star party season. We hope to see you.

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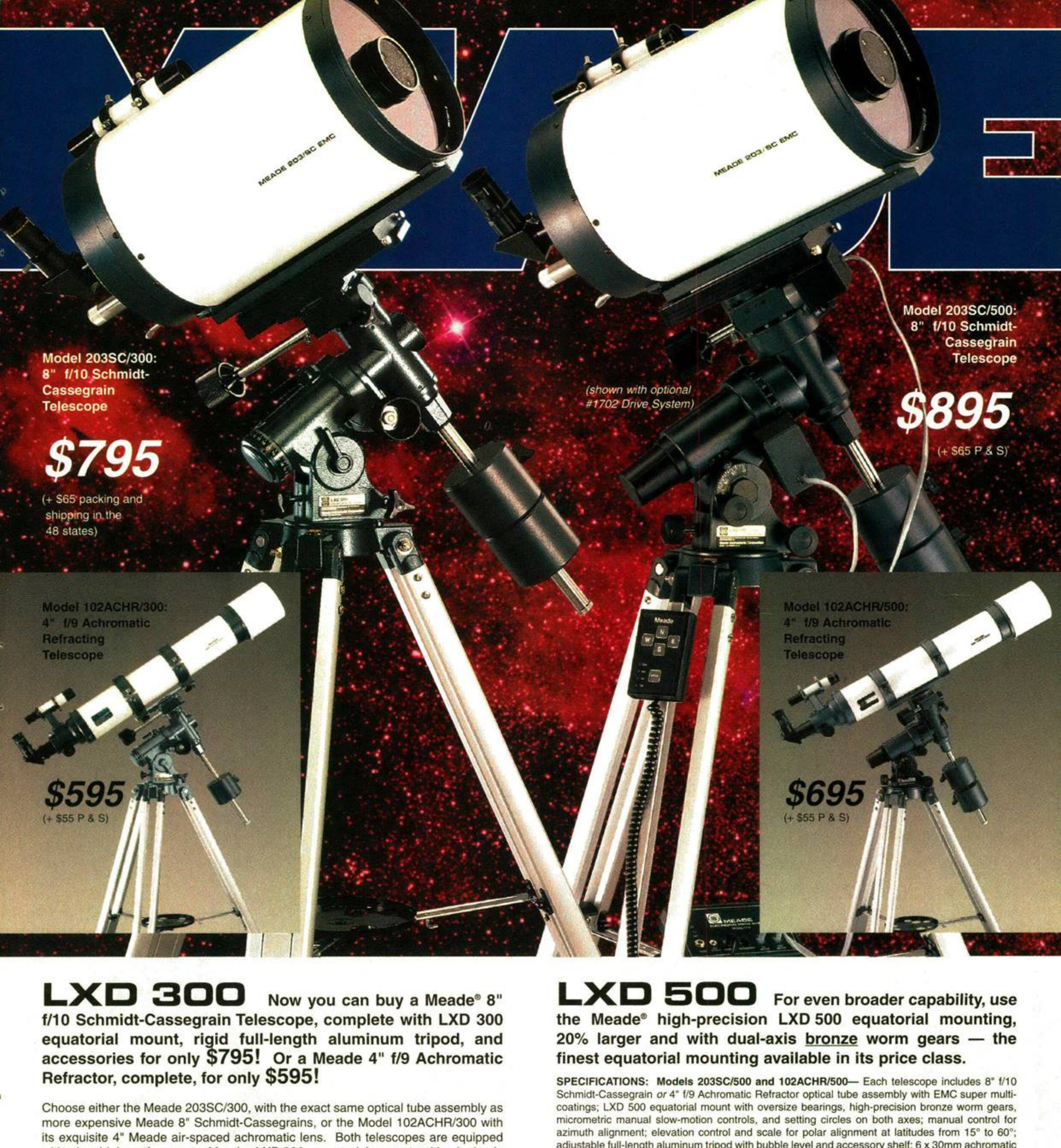
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8" f/10 Schmidt-Cassegrain Telescope
$795
(+ $65 packing and shipping in the 48 states)
(shown with optional #1702 Drive System)
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4" f/9 Achromatic Refracting Telescope
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LXD 300

Now you can buy a Meade® 8" f/10 Schmidt-Cassegrain Telescope, complete with LXD 300 equatorial mount, rigid full-length aluminum tripod, and accessories for only $795! Or a Meade 4" f/9 Achromatic Refractor, complete, for only $595!

Choose either the Meade 203SC/300, with the exact same optical tube assembly as more expensive Meade 8" Schmidt-Cassegrains, or the Model 102ACHR/300 with its exquisite 4" Meade air-spaced achromatic lens. Both telescopes are equipped with the high-performance Meade LXD 300 equatorial mount with dual-axis aluminum worm gears.

SPECIFICATIONS: Models 203SC/300 and 102ACHR/300 — Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 300 equatorial mount with aluminum worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 50°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions. **8" — $795** (+ $65 P & S); **4" — $595** (+ $55 P & S); **#535 R.A. Motor Drive System...$99; #812 Polar Alignment Finder...$49.**

LXD 500

For even broader capability, use the Meade® high-precision LXD 500 equatorial mounting, 20% larger and with dual-axis bronze worm gears — the finest equatorial mounting available in its price class.

SPECIFICATIONS: Models 203SC/500 and 102ACHR/500— Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 500 equatorial mount with oversize bearings, high-precision bronze worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 60°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions **8" — $895** (+ $65 P & S); **4" — $695** (+ $55 P & S); **#1701 R.A. Motor Drive System** with 4-speed controller...**$145; #1702 Dual-Axis Drive System** with 4-speed controller...**$195**; **#812 Polar Alignment Finder...$49.**

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MEADE LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).*

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

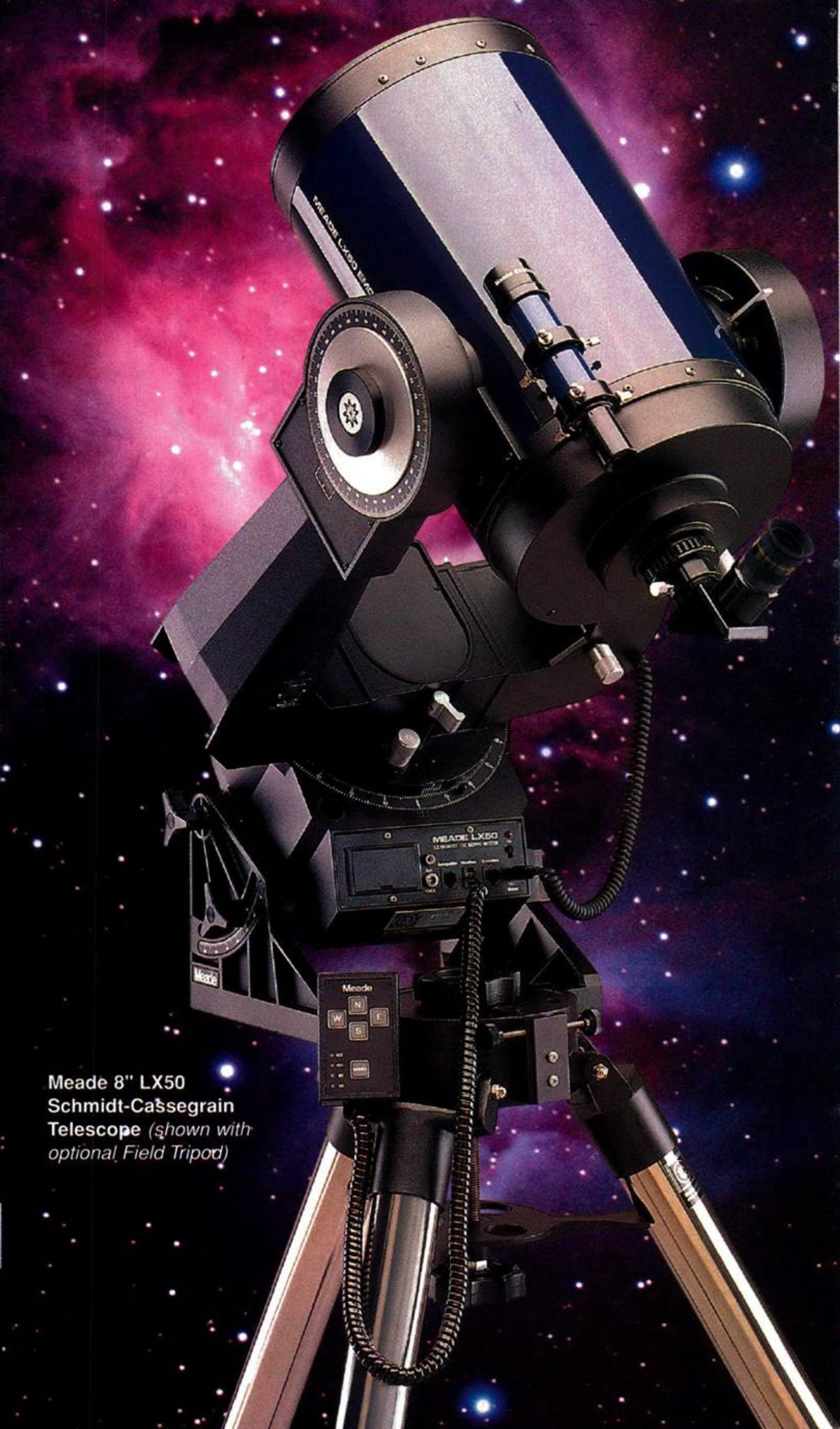
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

Meade 10" LX200 Schmidt-Cassegrain Telescope

Prices shown are suggested U.S. national mail-order retail prices.

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MEADE LX200
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The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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MEADE STARFINDER DOBSONIANS

Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right)*, tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- 1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- 1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- 2 - **Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

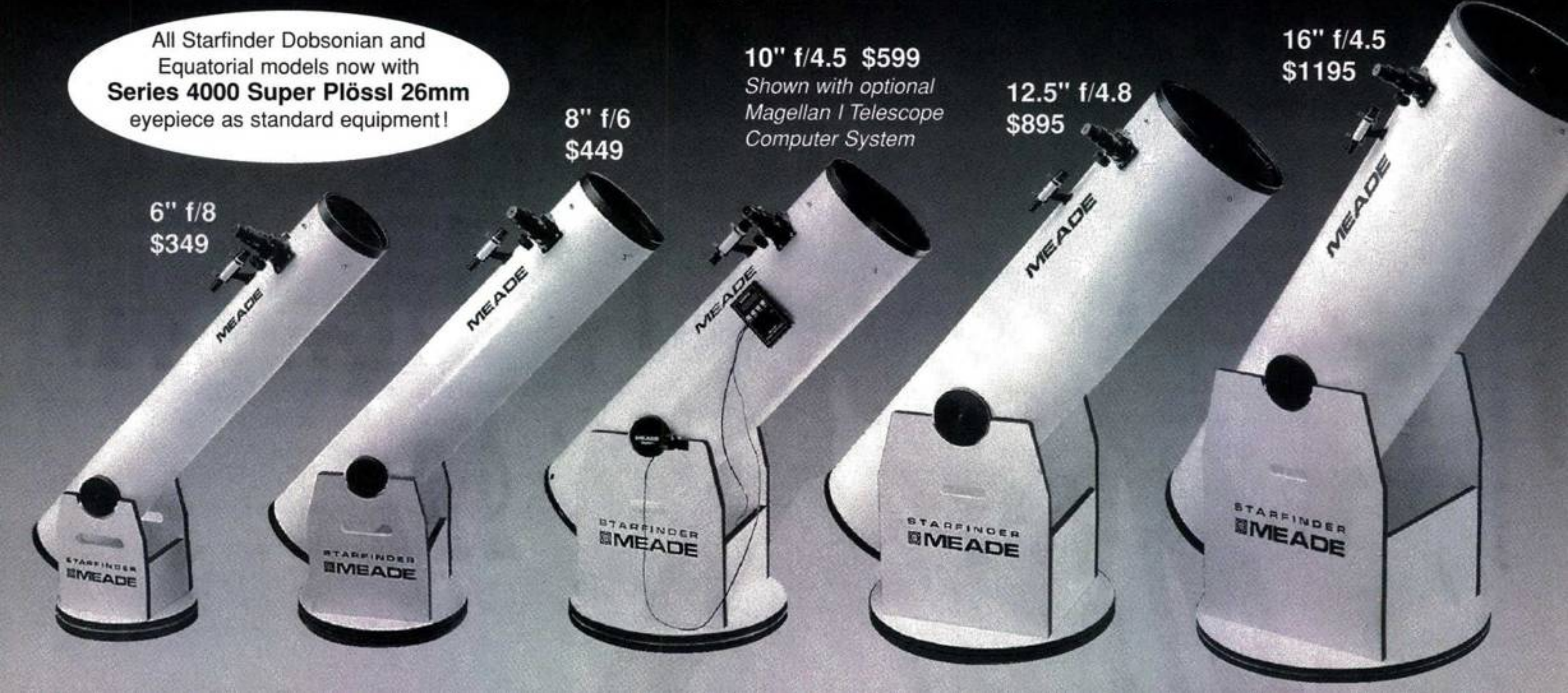
7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" . . . . $295.

Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All Starfinder Dobsonian and Equatorial models now with **Series 4000 Super Plössl 26mm** eyepiece as standard equipment!

6" f/8 $349

8" f/6 $449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12.5" f/4.8 $895

16" f/4.5 $1195

MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 1999-2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

MEADE
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
N
W
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S

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ☐ *A NASDAQ company.*
6001 Oak Canyon, Irvine, California 92620 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*

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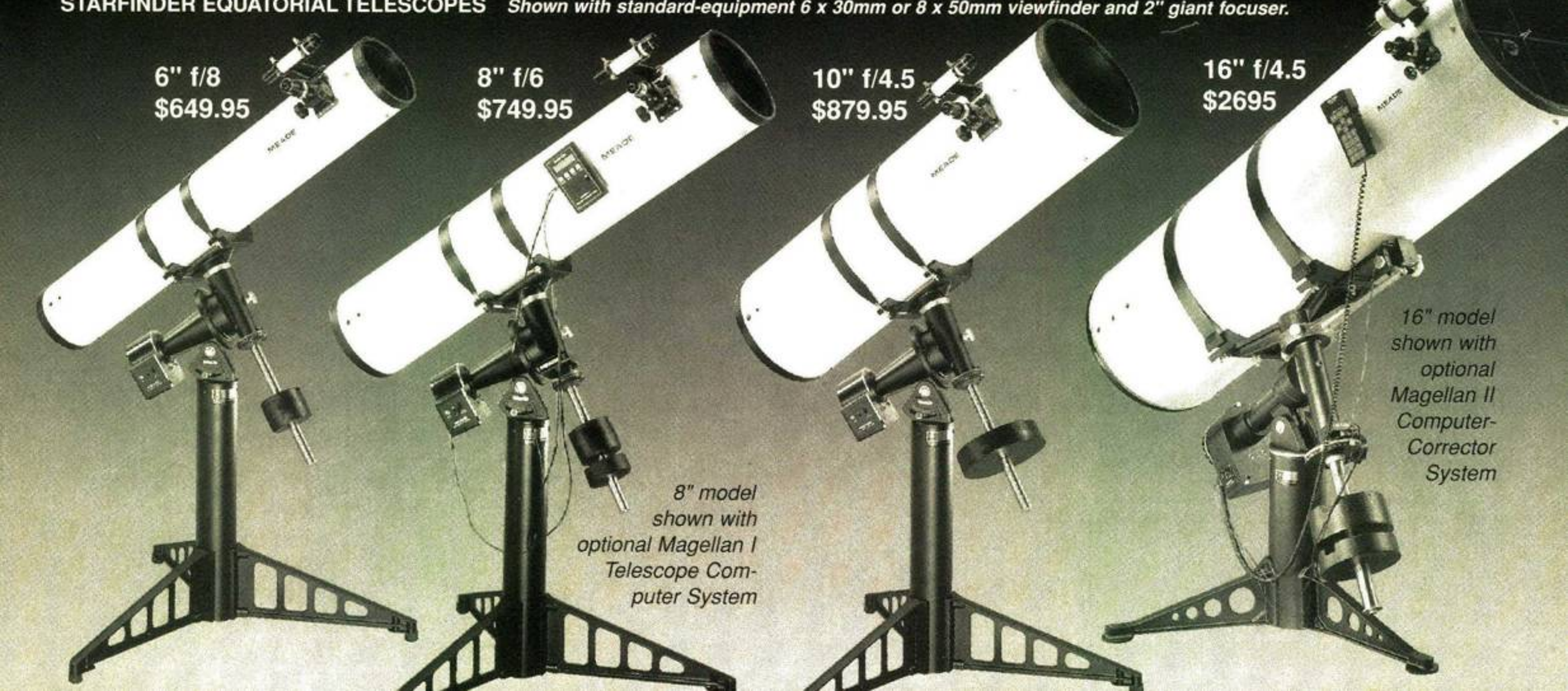
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

MEADE RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

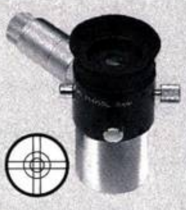
#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

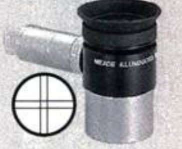
#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

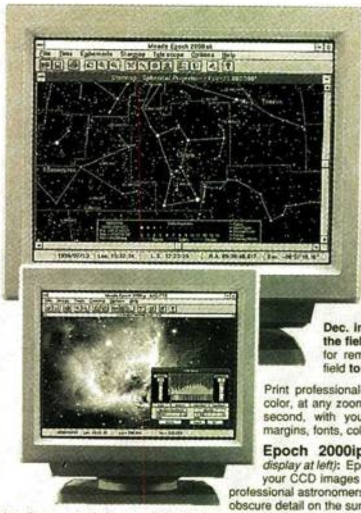
#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!
MEADE
FLIP-MIRROR SYSTEM
MEADE

#644
MEADE
FLIP-MIRROR SYSTEM

#647
MEADE
FLIP-MIRROR SYSTEM



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)***:** Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 .... **$199**

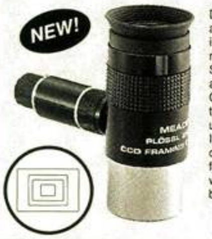
4000 f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular



Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

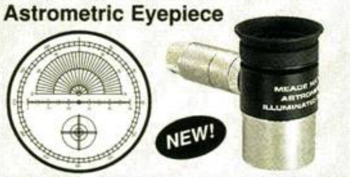
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

ETX® Deluxe Field Tripod

Custom-designed by Meade specifically for ETX-90 and ETX-125 Astro Telescopes. Tripod height adjusts from 34" to 54", for seated or standing observations. Micrometric controls in azimuth and elevation permit precise polar alignment of the ETX fork mount. Tripod head tilts and locks to 90° for terrestrial applications. Telescope attaches to tripod in seconds with 2 thumbscrews. All-aluminum construction. **$199.95** (10.00)

ETX® Hard Carrying Cases

NEW!

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

#774 Case for ETX-90 models: **99.95** (8.58)

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A Thousand Curses

Sharon Begley's story "Cosmic Flood" (June 1999) ought to elicit a torrent of anger upon NASA and everyone associated with it. They've effectively wasted untold millions of taxpayers' dollars on data that are now irretrievable and worthless, and they just keep on doing it.

Let's see. How many projects are currently underway gathering data on stars and planets by NASA and other research entities using taxpayers' money? Dozens? Scores? More? How much of that new information, gathered at absolutely prodigious rates, is going to be lost because the agencies can't analyze and make sense of it? How much of the valuable data now lost because they weren't analyzed is having to be gathered again? While everyone's out flying rockets and building bigger and better telescopes, who's minding the store?

Y'know folks, it's said that the current generation is the most scientifically illiterate in many a year. Is it any wonder, given such preposterous wastefulness on the part of the scientific community, that people have just gotten sick of science and scientists? We owe Ms. Begley a big round of applause and thanks for putting this mess before the public. — *Bill Mayers, Canastota, New York*

Contrary to the impression created by Sharon Begley's story, as well as the previous letter, scientific data acquired from NASA space missions are not lost, nor unanalyzed, nor underused.

Data acquired from NASA space missions are analyzed and interpreted, with results published in scientific journals, as well as being shared with the public through news media and other forums. The exciting science results and advancement of our knowledge and understanding of the universe from missions such as the Hubble Space Telescope, the Galileo mission to Jupiter and its moons, Mars Pathfinder, Mars Global Surveyor and Solar Heliospheric Observatory are the best witnesses.

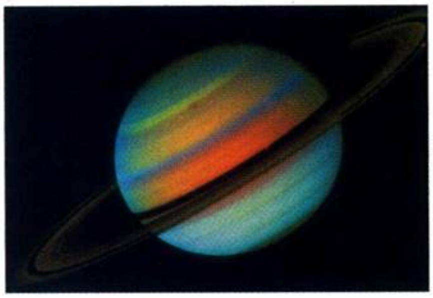
NASA selects (through open solicitations) and funds principal investigators who build the instruments flown on the missions to process and analyze that data and to archive the data products so that they can subsequently be accessible to the broader science community for analysis and interpretation. NASA funds guest observers and investigators for its missions; they are selected via peer reviewed competitions to analyze and fully exploit the science data. It also funds peer-reviewed research and analysis using data from the open archives, including data from missions no longer operating. All told, this involves several hundred investigators. — Joseph Bredekamp, Senior Executive for Information Systems and Data Archive in the Office of Space Science, NASA, Washington, D.C.

More Fun With Astronomy

How refreshing to read Steven Miller's letter (June 1999). At last, a like-minded individual. Who indeed says that science shouldn't be entertaining? The fun is out there.

Unfortunately, here in England it's becoming increasingly difficult to find it. The people we met at a beginner's astronomy class looked down their noses at our inexperience, overlooking our enthusiasm. Likewise, British magazines we once read assumed that their audience possessed degrees in physics and associated sciences. We just love the stars, planets, and anything in the light-polluted night skies we are lucky enough to see.

Like Steven, we have amused neighbors by spending whole nights lying on lounge chairs, wrapped in blankets, woolly hats, and fluffy socks, gazing skyward, hoping to see something unusual or even usual. We have yet to master our telescope and see something other than the moon. What a joy it will be to see Saturn's rings "in the flesh." Even so, we are excited, fascinated, and amused by everything and anything and are learning all the time. This thing is addictive.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Yes, it is an entertaining, pleasurable, amusing, and interesting pastime, and we love it even though the people around us think we are completely bonkers and consider us eccentrics. — *Janice Guyton and Barbara Elliott, London, England*

Too Hot or Too Cold?

Your AstroNews note in the July 1999 issue on the "Greenhouse Riddle Modeling Deepens Mystery of Earth's Heat" was well written and informative, but for an error in the conversion from units of °F to °C. The problem arises because those who did the arithmetic assumed one was referring to temperature measurements versus differences in temperature. The correct equation for differences in temperature using the two nominal scales of Fahrenheit and Celsius is 1° F = $\frac{5}{9}$° C. The appropriate temperature variations should thus read 63° F (35° C not 17° C), 90° F (50° C not 32° C), and 16° F (8.9° C not –9° C).

The need to regard these temperature differences as such is particularly obvious when one reads the last sentence of the second-to-last paragraph, where it is written: "This combined effect cools Titan's surface by 16° F (–9° C)." It is rather difficult to view a cooling effect of 16° F being equivalent to a net temperature increase, i.e. heating effect. — *Dennis G. Garratt, Ontario, Canada*

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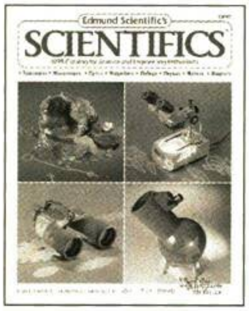

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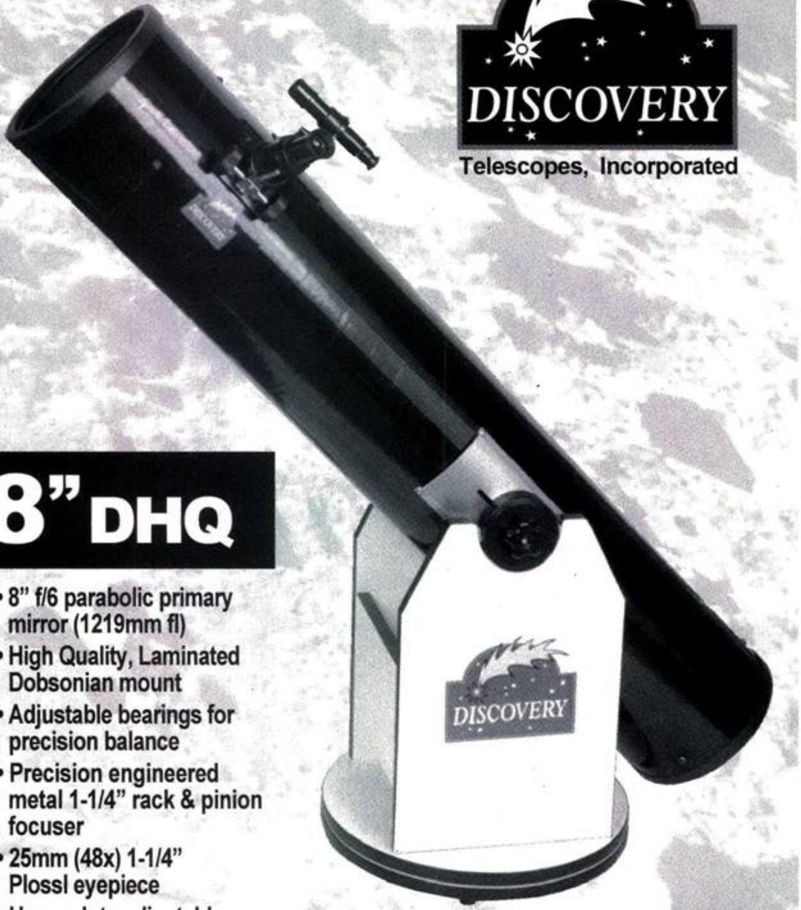

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Flag Watch in Tacoma

The Tacoma Astronomical Society (TAS) often sets up scopes in one of our favorite skywatching sites and invites the public to join us for a look at the sky. Recently I set up my Dobsonian with Ken Slavin, and we were showing the moon to a lady and some children. Some of the children had peeked through the scope at the moon and asked where to look for the U.S. flag that the astronauts had planted. The lady also wanted to know why the flag was nowhere to be found. I glanced at my watch and politely told her it was after 5 P.M. and the flag had already been taken down. She just looked surprised and walked away. *— Leo Romo, Tacoma Astronomical Society, Washington*

Too Many Translations

Astronomy often gives a parenthetical description of distances for things such as parsecs and astronomical units. I understand the reason for these descriptions but I think they slow down the reading of the article and the many of us who understand what these units are get annoyed when having to read the explanation every time it appears in a new article. I suggest perhaps a quick reference somewhere in the magazine that, in every issue, gives a small chart so people unfamiliar with these distances can understand them.

As I was reading AstroNews in your August issue, I noticed an elementary mistake. In the article about the close approach of stars and their effect on the Oort Cloud, Hubble's Constant is cited and the units (kilometers per second per megaparsec) are compared to light-years incorrectly. The article claims that one megaparsec equals about 3.26 light-years, which is obviously one parsec, not a megaparsec. — *Scott Zilmer, Washington, D.C.*

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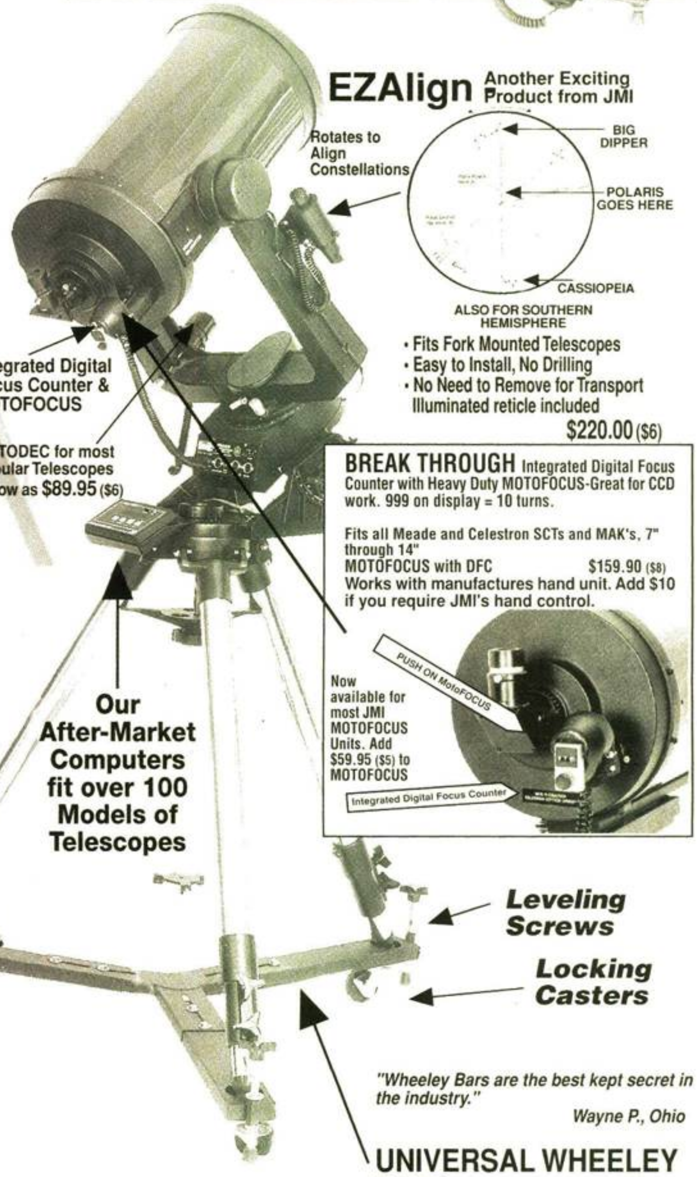

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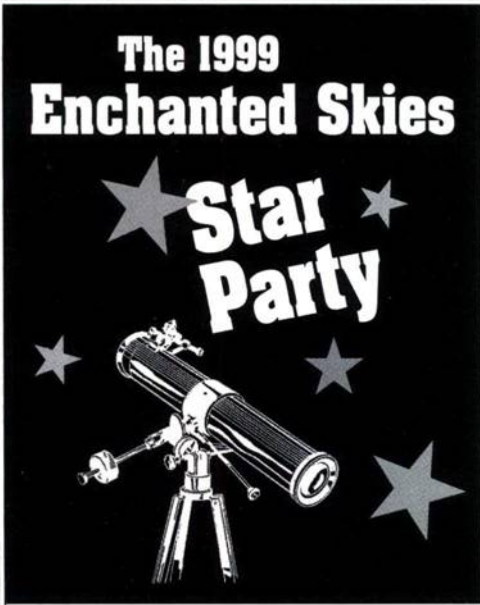

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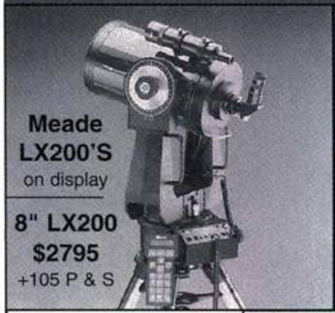

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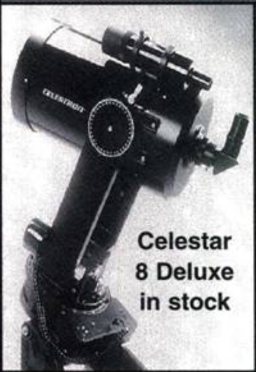

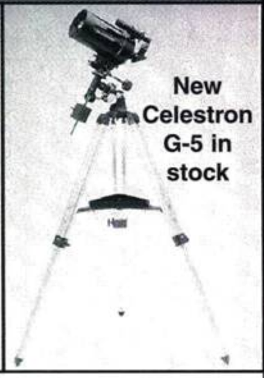

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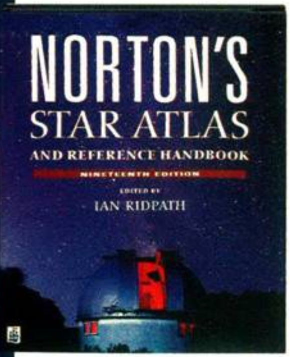

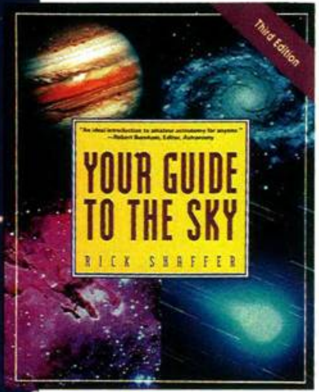

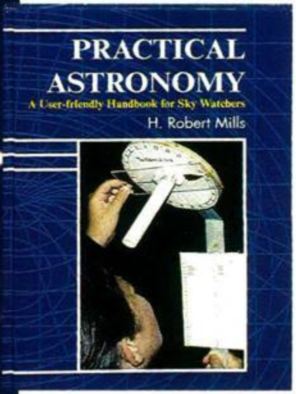

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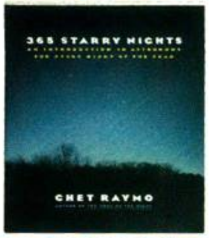

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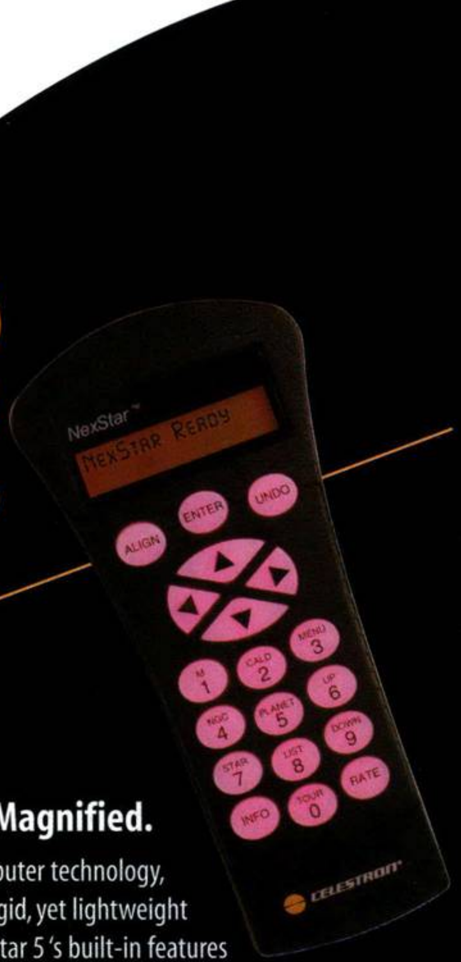
What makes the new Celestron NexStar™ 5 the most revolutionary computerized GOTO telescope on Earth?

It's simple.

The new Celestron NexStar 5 Schmidt-Cassegrain Telescope takes simplicity of use into a new dimension. A design and engineering tour d'force, the NexStar 5 combines a unique sculptured fork arm and drive base, state-of-the-future electronics, advanced mechanical engineering, and Celestron's renowned optics. Add to that an array of operation, convenience and software features that are optional or unavailable on most other GOTO telescopes. The result is nothing less than the perfect telescope for the first-time buyer who wants to start touring the Universe with virtually no learning curve or complicated set-up, or the serious amateur looking for advanced features not found on other GOTO telescopes.



NexStar 5. Technology Magnified.

Combining state-of-the-art computer technology, simple altazimuth operation, rigid, yet lightweight and portable design, the NexStar 5's built-in features will enhance your stargazing experience and make exploring our Universe easier than you ever thought possible. The NexStar 5 features include:

Easy Set-up — There is no complicated set-up. Simply align two stars and let the NexStar automatically find the objects for you. Or, use the Auto Align feature and the telescope picks the alignment stars for you. The NexStar 5 can be positioned on a tabletop or an optional tripod. For long exposure astrophotography, use the telescope in the equatorial configuration by adding an optional wedge.

Aluminum Construction — All load bearing components (fork arm and drive base) are made of aluminum for rigid low vibration performance.

Optical Tube — Celestron's legendary 5" 1250 mm f/10 Schmidt-Cassegrain optics is noted for its razor sharp image quality. The large 5" aperture allows you to clearly view deep space objects like galaxies, nebulae, clusters and double stars. An optional f/6.3 Reducer/Corrector provides a wider field and faster imaging.

CELESTRON®

Star Pointer Finderscope — The quickest, easiest way to point your NexStar to any object in the sky.

25mm Plössl Ocular Included — For 50x magnification and a field of view over one degree!

Hand Controller —The standard hand controller, which can be used mounted to the fork arm or extended for remote use, has illuminated buttons and a LCD. The buttons are backlit with red LED's to retain your night vision. An RS232 communication port enables the NexStar to be controlled by your laptop or PC.

18,000+ Object Database — The object database includes the entire Revised New General Catalog, Messier Catalog, Caldwell Catalog and selected stars from the SAO Catalog. There are also customized lists of famous objects.

Tour Function — Tour seeks out all of the best objects for a given month and leads you on a guided tour of the night sky complete with descriptive information about each object.

Variable Slew Speeds — Nine slew speeds, from photo guide rates to fast slew rates up to 6.5 degrees per second. Tracking rates include sidereal, solar, lunar and King.

Quiet Operation — High precision servo motors provide long life, quiet operation and accurate pointing.

Power Options — An AC adapter is supplied with the telescope. Also can be powered with eight user-supplied AA batteries (the battery compartment cover is conveniently located on the top of the base), or optional cigarette lighter adapter.

NexStar 5.
As Simple As It Gets.

The NexStar 5 is the down to earth answer to starting an exciting exploration of the Universe. For a brochure or a closer look at this stunning instrument, visit an authorized Celestron dealer, or visit the Celestron website.

It's that simple.

Celestron
NexStar

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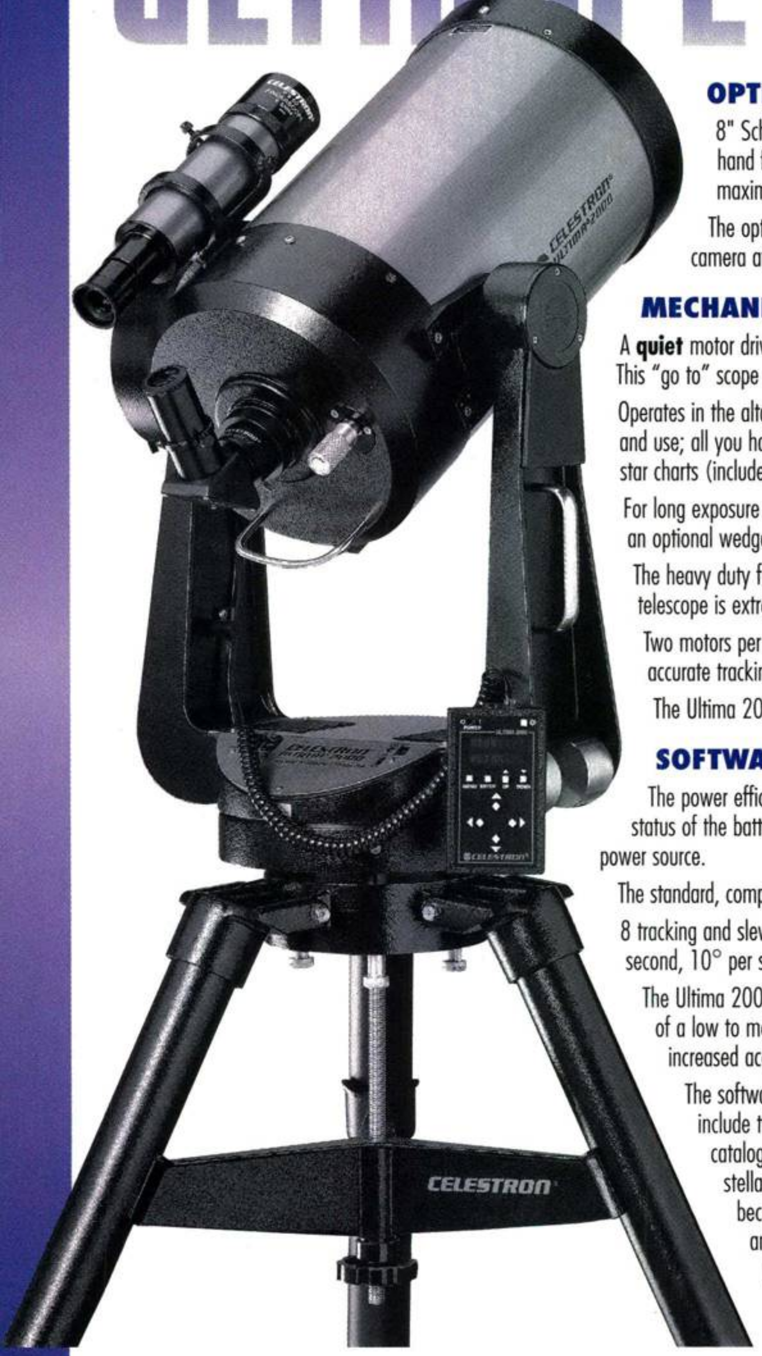
THE UNIVERSE IS JUST A CLICK AWAY WITH THE ULTIMA 2000

Combining state-of-the-art computer technology with a very stable fork mount and superb Celestron optics makes exploring our Universe fun, easy and exciting.



OPTICS

8" Schmidt-Cassegrain Telescope, 2032mm Focal Length, f/10. Each optical system is individually hand figured and guaranteed to be diffraction limited. Multi-coated Starbright® coatings group for maximum light transmission and bright, high contrast images.

The optics are Fastar compatible which provides the potential for CCD imaging using the PixCel CCD camera at an incredible f/1.95! Deep sky images in 30 seconds or less.

MECHANICAL FEATURES

A **quiet** motor driven "go to" computerized telescope built entirely at the Celestron factory in Torrance, California. This "go to" scope won't disturb your neighbors.

Operates in the altazimuth configuration allowing you to find most objects in seconds. Simple to set up and use; all you have to do is find two alignment stars which are easily located on the laminated monthly star charts (included).

For long exposure astrophotography or CCD imaging, use the telescope in the equatorial configuration by adding an optional wedge.

The heavy duty fork mount is extremely rigid and sits on top of a sturdy, adjustable metal tripod. Yet, the telescope is extremely portable and convenient to take with you.

Two motors per axis are standard as well as precision worm gears in both axes that provide very smooth, accurate tracking ability.

The Ultima 2000 can be moved manually (by hand) without losing its star alignment.

SOFTWARE/ELECTRONICS FEATURES

The power efficient DC telescope is operated with the included AA batteries. A built-in voltmeter monitors the status of the batteries. Optional adapters are available to run the telescope from a car battery or from an AC power source.

The standard, compact hand controller operates the various functions such as position, identify, speed, pointing, etc.

8 tracking and slewing speeds are available – sidereal, solar, lunar, King, 2x sidereal, 0.5x sidereal, 2° per second, 10° per second.

The Ultima 2000 has impressive pointing accuracy where the object selected will always be in the field of view of a low to medium power eyepiece. Includes Enhanced Encoder Resolution and Relative Go To mode for increased accuracy which is ideal for centering objects on a CCD chip.

The software database contains over 10,000 deep-sky objects as well as major planets. The objects include the entire Revised New General Catalog, the Messier catalog, selected objects within the IC catalog and the ESO and Uppsula catalogs, 241 interesting double and multiple stars, and 661 non-stellar objects. The database may not be the largest in the industry but it is one of the most useful because of the object selection. In addition, the display of the object data is the most complete of any commercial computerized telescope.

For beginners and educators, a special Tour mode is available which allows you to view 15 popular objects by season, automatically.

To quickly and easily find your favorite objects, the telescope offers 25 user-defined selections.

The Ultima 2000 can by operated by a computer using popular astronomy software such as *The Sky*. Programs can also be written by the user to control the telescope.

Other standard features and accessories include: 9x50 finderscope, multi-coated 26mm Plössl eyepiece – 1¼" (78x), star diagonal – 1¼", LED display, auto guider port, northern and southern hemisphere operation, comprehensive instruction manual.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
Visit our Web site at www.celestron.com

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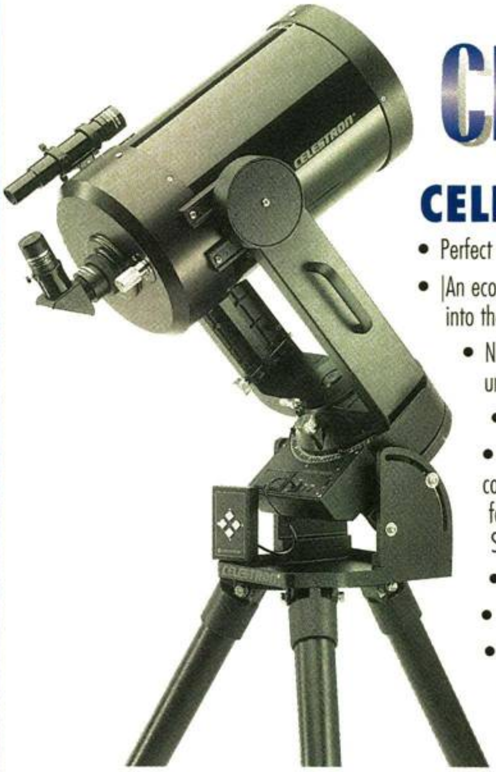
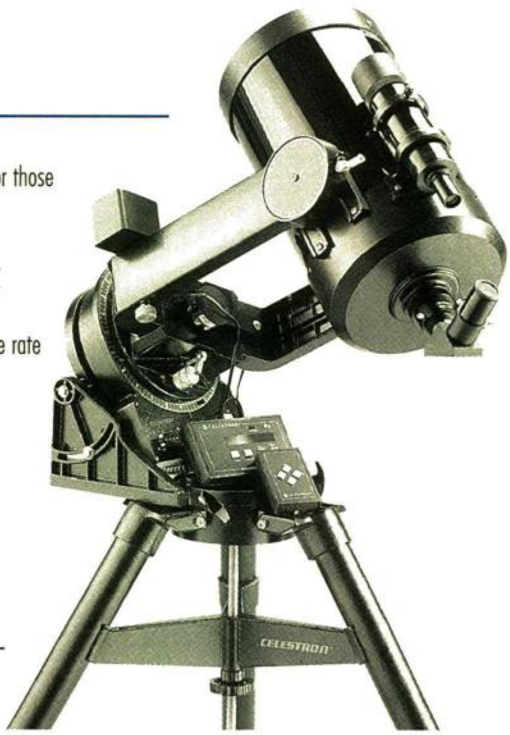
CELESTAR 8 TELESCOPES



CELESTAR 8

- Perfect for a first time astronomer.
- An economical but full featured 8" (2032mm f/10) Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8.
- No sacrifice was made in the optics. Celestron's carefully hand-figured system delivers diffraction-limited optics of unsurpassed quality. Starbright® coatings are standard.
- The energy efficient DC electronics are powered by a 9 volt alkaline battery for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the Sky & Telescope review – "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90.°
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – $1\frac{1}{4}$" and a 25mm SMA Eyepiece – $1\frac{1}{4}$" (81x).
- Weight – 41 pounds.

CELESTAR 8 DELUXE



- For the more serious astronomer.
- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging with the PixCel or other CCD cameras.
- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a large 9x50 Finderscope, Star Diagonal – $1\frac{1}{4}$" and a multi-coated 26mm Plossl Eyepiece – $1\frac{1}{4}$" (78X).
- Weight – 52 pounds.

ADVANCED ASTRO MASTER®

Advanced Astro Master

The Celestar 8 Computerized and the Celestar 8 Deluxe Computerized telescopes are the same as the Celestar 8 and Celestar 8 Deluxe but with the addition of a factory installed and tested Advanced Astro Master.®

Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery.

Contains an RS-232 serial interface to enable usage with programs like "The Sky"™ by Software Bisque.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron. **Visit our Web site at www.celestron.com**

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NEAR-EARTH ASTEROIDS

Earth Could Mold Asteroids

▶ Earth's nearest neighbor, the moon, does far more than shed light into an otherwise dark night sky. By raising gravitational tides, it also subtly changes the shape of our planet. But that's nothing compared with what Earth does to the moon. With its much greater gravity, Earth raises significant tides in the solid moon, noticeably distorting its shape.

Astronomers are now learning that Earth can raise even more havoc with some of the smallest members of our solar system: the asteroids. Reporting in the April 1999 issue of *The Astronomical Journal*, William Bottke of Cornell University and his colleagues make the case that Earth can take a fairly spherical asteroid and stretch it into the shape of a lumpy cigar.

One such distorted stogie is asteroid 1620 Geographos. It was imaged by radar during its 1994 close approach to Earth and measured 3.18 miles by 1.15 miles (5.11 km by 1.85 km) in diameter. Geographos displays a shape, orbit, and rotation rate that suggest it was significantly altered sometime in the past by the tidal forces of a planet.

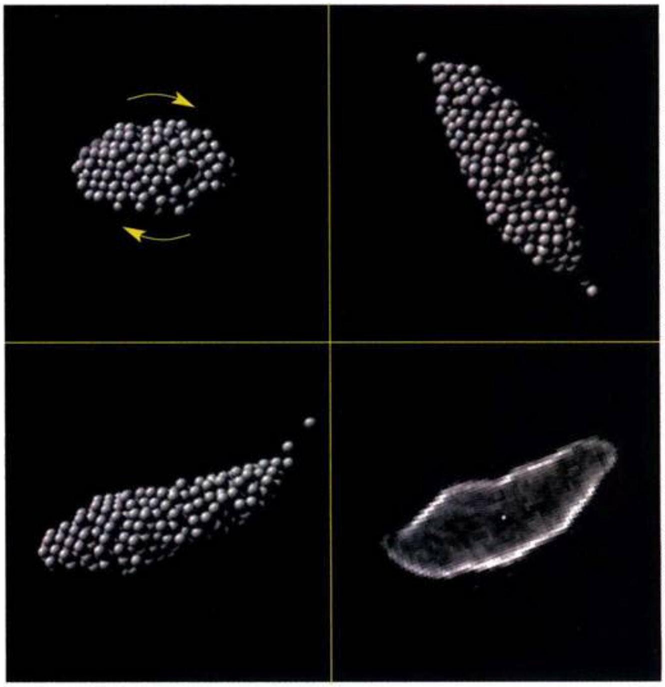
For tides to significantly change the shape of an Earth-crossing asteroid, the object must pass close to either Earth or Venus at a fairly slow speed (so that gravitational forces can act for a longer time). No one knows whether Geographos did, but computer models show that asteroids like it have a pretty good chance of doing so.

The asteroid also must have little internal strength. Astronomers now believe that most asteroids (and comets, for that matter) from roughly a mile to several miles in diameter resemble "rubble piles" — a collection of smaller fragments held together by their collective gravity, not by the strength of the material. Comet Shoemaker-Levy 9 provided a perfect example when Jupiter's gravity split it into more than a dozen pieces. In addition, many of the asteroids observed by spacecraft have a low density. Mathilde, for example, comes in at only 1.3 grams per cubic centimeter, which is such a low value that its interior must contain voids.

Perhaps most interesting, the research team modeled what would happen to a rubble pile during a close encounter with a planet. They found that a planet's tides can transform a typical rubble pile into a highly elongated object resembling Geographos. Indeed, the model even reproduced all the main features of that asteroid. The rotation rates of the asteroids produced by the model also closely match that of Geographos.

Because it's impossible to follow the orbit of any Earth-crossing asteroid for more than a few hundred years, no one can say whether Geographos ever came close enough to a planet to be deformed. But the research team did find that a small fraction of Earth crossers should have shapes and spins similar to Geographos. They conclude that planetary tides should be added as an important geological process capable of modifying small solar-system objects.

— Richard Talcott



William Bottke (Cornell University), et. al.

Steven Ostro (NASA/JPL) et. al.

Three computer-generated models show how tidal forces stretch and shape a rotating rubble pile passing close to Earth. The third shape, lower left, is nearly identical to the asteroid Geographos, lower right.

TELESCOPES

Gemini Telescope Debuts Beautifully

▶ The first images obtained by the new 8-meter (315 in) Gemini North Telescope atop Hawaii's Mauna Kea show that it has the power to resolve an automobile's headlights from 2,000 miles (3,200 km). The images show a distant star-forming region, a gorgeous planetary nebula, and a cluster of stars. However, there is more to Gemini than spectacular imagery.

"What strikes me is not what you see, but what you hear when the telescope is slewing from one object to another," says associate project scientist Phil Puxley. "You don't hear anything; the telescope is absolutely silent." The smooth operation is made possible with a

ACCESSORIES BY CELESTRON

The Celestron Accessories here are universal – use with virtually any telescope.

PLÖSSL EYEPIECES

In a recent *Sky and Telescope* review, Celestron's 1¼" Plössl eyepieces were rated as **top ranking**, and found to outperform many similar, but more expensive eyepieces. An exceptional value! Celestron offers these premium eyepieces at affordable prices, yet they're among the best designed and corrected eyepieces available. They're **multicoated** for enhanced contrast and all models are threaded to accept Celestron colored eyepiece filters. **Focal length with field of view:** 6.3mm (52°), 7.5mm (52°), 10mm (52°), 12.5mm (52°), 17mm (52°), 20mm (52°), 26mm (50°), 32mm (52°), 40mm (46°).

ULTIMA® EYEPIECES

These are Celestron's top of the line 1¼" eyepieces. They feature long eye relief and a wide field, and each air-to-glass surface is **fully multicoated** to enhance contrast levels. These special eyepieces are computer designed to keep visual aberrations to an absolute minimum. Recently, *Sky and Telescope* reviewed Celestron's Ultima® eyepieces and rated them **best in their class**, with greater contrast and image sharpness than the competitive models of other manufacturers. The inside surfaces and edges of all lenses are blackened, to keep out reflected light. Threaded barrels accept Celestron thread-in filters. **Focal length with field of view:** 5mm (50°), 7.5mm (51°), 12.5mm (51°), 18mm (51°), 24mm (51°), 30mm (50°), 35mm (49°), 42mm (36°).

LV EYEPIECES

These Vixen brand 1¼" eyepieces (6 to 8 elements) are a new breed, using the rare earth glass lanthanum in one of their field lenses, for almost total freedom from any visual aberrations. All focal lengths have a comfortable 20mm of eye relief. Even when using the 2.5mm LV eyepiece on a telescope, you'll have eye relief of 20mm! These eyepieces also feature **fully multicoated** lenses for optical excellence. **Focal Length with field of view;** 2.5mm (45°), 4mm (45°), 5mm (45°), 6mm (45°), 9mm (50°), 10mm (50°), 12mm (50°), 15mm (50°), 20mm (50°), 25mm (50°).

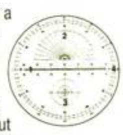
LV ZOOM EYEPIECE

This super premium 1¼" zoom eyepiece has a focal length of 8mm to 24mm. It is the finest zoom eyepiece for low to medium power observing. It's an excellent eyepiece that performs superbly, with **fully multicoated** surfaces. It offers an apparent field of 40° at 24mm and 60° at 8mm. Eye relief ranges from 15mm to 19mm.

CROSS HAIR EYEPIECE

This 1¼" eyepiece is of the Kellner design, with a focal length of 20mm. It's ideal for centering alignment stars when using digital setting circles or computerized telescopes. A useful all-around eyepiece for many applications, including terrestrial observing.

MICRO GUIDE EYEPIECE



This multifunction 1¼" guiding eyepiece features a laser-etched reticle with a built-in battery illuminator. The eyepiece is a **multicoated** 12.5mm Orthoscopic. Usage possibilities include: direct guiding on stars outside the center of the field of view; greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude; and measuring position angles and separation of double stars. **Its finely etched micrometer scale** has gradations 50 microns apart and 15 microns wide. Included are: the eyepiece, built-in cordless illuminator with adjustable brightness control, batteries and instructions.

BARLOW LENSES

Celestron's premium quality .96" and 1¼" achromatic Barlow lenses are compact and lightweight. Both are under three inches long, with the 1¼" lens weighing in at 4 ounces and the .96" lens a mere 2 ounces! The clear aperture is 27mm on the 1¼" model, and 21mm on the .96" unit. The .96" Barlow is **fully multicoated** and the 1¼" lens is **multicoated**. The Ultima® Series Barlow (2x – 1¼") is an air-spaced, three element apochromatic design with a 27mm clear aperture. This lens features a very high quality, **fully multicoated** design. Amazingly compact and lightweight, it's just 5 ounces and 2¾" in length.

DIAGONALS

Celestron's Erect Image Diagonals are an Amici prism design. This design allows you to look into the telescope at a 45° angle, at images that are oriented properly, meaning the image is upright and correct from left to right. .96" to 1¼" models are available. Use of Celestron's hybrid .96" to 1¼" 45° Erect Image Diagonal on a telescope equipped with .96" eyepieces means greater versatility. This diagonal will allow you to use 1¼" eyepieces to obtain a larger field of view and better eye relief. A 90° 1¼" Erect Image Diagonal is available for those who prefer that angle. A 1¼" Star Diagonal (90°) is also available.

EYEPIECE FILTERS

Eyepiece filters are an invaluable aid in lunar and planetary observing. They reduce glare and light scattering, increase contrast through selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue. Celestron's filters are made of high quality, solid plane parallel glass with excellent homogeneity. They're **antireflection coated** to prevent glaring and ghosting. All eyepiece filters are threaded to fit Celestron's, and most other manufacturer's, 1¼" eyepieces, and offer a full 26mm clear aperture. Filters available individually are: #12 Deep Yellow, #21 Orange, #25 Red, #58 Green, #80A Light Blue, #96 – 25% T, #96 – 13% T, Polarizing. In addition four different sets of four filters each are available.

1¼" POLARIZING FILTER SET

It's particularly useful for reducing glare while observing the moon, double stars, the planets and terrestrial subjects. You can vary the degree of transmission. By causing the amount of transmitted light to vary, the filters become, in effect, a continuously variable neutral density filter.

LPR FILTERS

Light Pollution Reduction (LPR) Filters are designed to selectively reduce the transmission of certain wavelengths of light, specifically those produced by artificial light. As a result, Celestron LPR Filters darken the background sky, making deep-sky observation of nebulae, star clusters and galaxies possible from urban areas. While blocking unwanted light, Celestron LPR Filters permit the transmission of more desirable wavelengths. This will improve your viewing of emission nebulae, both from urban and rural settings. They're also protected with a **broadband antireflection coating** to prevent ghosting and to improve contrast. They provide superior performance and contrast over competitive models. A 1¼" model threads into 1¼" eyepieces to work with virtually all telescopes.

MOON FILTERS

Celestron's Moon Filter threads into 1¼" eyepieces and aids in reducing the brightness of the moon and improving contrast, so greater detail can be observed on the lunar surface. The clear aperture is 21mm.

VIBRATION SUPPRESSION PADS

Telescope vibration is caused by windy conditions, an unsteady mount or tripod or even an accidental bump to the instrument, and results in reduced image quality. Celestron's set of three Vibration Suppression Pads **will reduce vibration time by almost 100%** and decrease vibration amplitude. The pads fit between the bottom of the tripod legs and the ground, a simple and functional solution to the problem of image disturbance.

NIGHT VISION FLASHLIGHT

Celestron's premium model for astronomy uses **two red LEDs** to preserve night vision better than red filters or other devices. Brightness is adjustable. Operates on a single 9 volt battery (included).

LENSPEN™

A superb new tool in optical lens cleaning technology. Perfect for cleaning binocular lenses, small aperture spotting scopes and telescopes, eyepieces, and other optical items. The LensPen™ comes with a handy retractable dust removal brush and a special non-liquid cleaning element, designed to never dry out. Safe and very easy to use.

SKY MAPS

Celestron Sky Maps are the ideal teaching guide for learning the night sky. You wouldn't set off on a road trip without a road map, and you don't need to try to navigate the night sky without a map either. Even if you already know your way around the major constellations, these maps can help you locate all kinds of fascinating objects. The front cover has a specially designed **luminous planisphere** that rotates to simulate the seasonal progression of celestial objects through the sky. When the planisphere is pre-exposed to light, star positions glow brightly against a dark background, mimicking actual constellations. More than a thousand stars and deep-sky objects are listed and charted.

PLANISPHERE

A simple and inexpensive tool for all levels of observers, from naked eye viewers to users of highly sophisticated telescopes. The Celestron Planisphere makes it easy to locate stars for observing and is a great planet finder as well. The Celestron Planisphere comes in three different models, to match the latitude from which you're observing: 20° to 40°, 30° to 50°, 40° to 60°.

TELESCOPE EQUATORIAL MOUNT–CG-3

A durable, rigid, German equatorial mount with a wooden tripod, offering both affordability and high quality. Designed as an excellent and inexpensive upgrade option when you're ready to move to a sturdier mount for your beginning telescope. R.A. and DEC setting circles, a latitude scale, slow motion controls and a handy accessory tray are included.

TELESCOPE EQUATORIAL MOUNT–CG-4

The CG-4 mount is a very rigid German equatorial mount. A counterweight, latitude scale, setting circles and slow motion controls on both axes are standard. The adjustable height aluminum, rigid tripod has **excellent damping characteristics** and a handy accessory tray. It is the same mount as used on Celestron HD telescopes and is a step up from the CG-3. Optional motor drives and a polar alignment finderscope are available.

TELESCOPE EQUATORIAL MOUNT–CG-5

The CG-5 EQ mount is the newest generation of Celestron's German mounts. Both axes of the equatorial mount have **precision worm gears** for extremely smooth motion. It is a step up from the CG-4. This **heavy-duty mount** delivers jitter-free images easily and the adjustable height aluminum, rigid tripod has excellent damping characteristics and a convenient accessory tray. Included are setting circles on both axes, slow-motion controls and latitude scale. An adjustable counterweight makes it easy to point, balance and use. An optional polar alignment scope for fast polar alignment as well as motor drives are available for easy tracking.

ALT-AZ PHOTO TRIPOD MOUNT

This heavy-duty mount is perfect for cameras with large telephoto lenses, and for spotting scopes and binoculars. If you already own a small telescope mount and are interested in one offering greater stability, the Alt-Az is an ideal upgrade. The adjustable wood tripod comes with two slow motion cables and is equipped with a ¼" x 20 photo head.

For more detailed information on these and other Celestron Accessories, contact a Celestron dealer or Celestron. Visit our Web site at www.celestron.com

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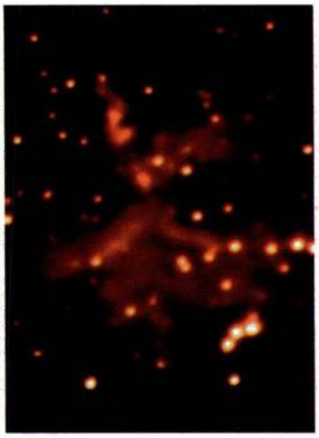
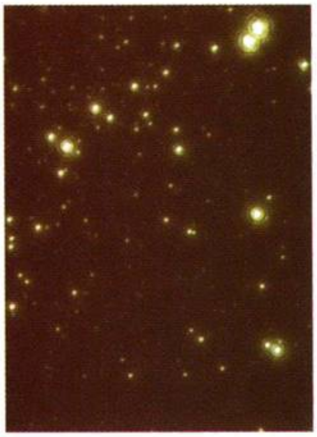


This Gemini infrared image reveals a distant star-forming region in the Milky Way Galaxy called G45.45+0.06.

The young planetary nebula BD+303639 is glowing in hydrogen light in this Gemini near-infrared image.



These stars shine within the central region of NGC 6934, a globular cluster 50,000 light-years from Earth.

Gemini Observatory, NSF, Univ. of Hawaii Institute for Astronomy

thin layer of oil — instead of conventional, mechanical telescope bearings — that supports Gemini North's 377 tons.

The telescope's resolving power (0.083" for infrared images and 0.09" for a visible-light image) rivals the 2.4-meter (94 in) Hubble Space Telescope. The resolution is made possible by the large size of the primary mirror and adaptive optics technology that removes the "twinkling" effect of visible and infrared light as they pass through atmospheric disturbances. In a possible move that would boost Gemini North's resolving power by a factor of 50, scientists are discussing a proposal to join it electronically with three nearby telescopes — the 10-meter (394 in) Keck I and II telescopes and the 8.3-meter (327 in) Subaru Telescope. "It's only been talked about," says Puxley. "It certainly could be made to work, and there is interest in doing so on all sides." That foursome atop Mauna Kea would rival the expected resolving power of the Very Large Telescope, a closely spaced network of four 8.2-meter telescopes currently under construction at the Paranal Observatory in Chile.

Seven nations are financing the $192-million Gemini project, which includes a twin of Gemini North under construction on Cerro Pachón in northern Chile. Scientists from the sponsoring countries will be apportioned observing time on the Gemini telescopes based on their nations' relative contributions: United States, 48 percent; United Kingdom, 24 percent; Canada, 14 percent; Australia, 5 percent; Chile, 5 percent; Argentina, 2.5 percent; and Brazil, 2.5 percent.

— Rex Graham

NEUTRINOS

First Neutrino Light Detected at Sudbury

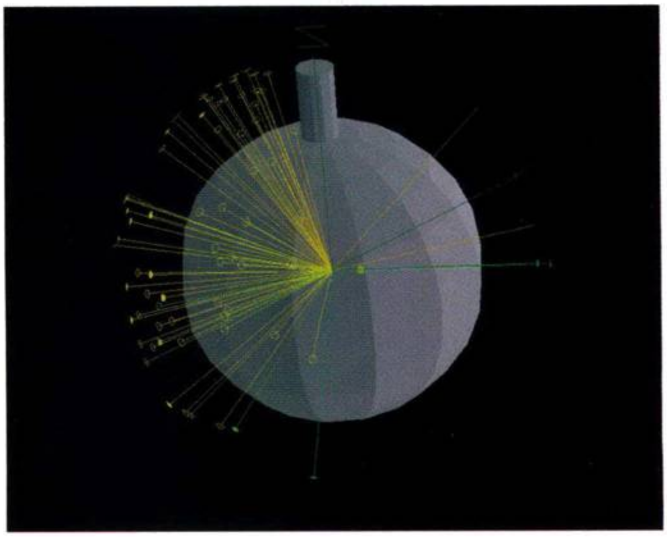
▶ Astrophysicists studying subatomic neutrino particles produced in the sun's core by supernova explosions and other processes have heralded "first light" with a new neutrino observatory near Sudbury, Ontario. To the delight of researchers, the Sudbury Neutrino Observatory (SNO) has been recording about 10 neutrinos a day since it went into operation in April.

"We will analyze these signals for some time," says physicist Doug Hallman of Laurentian University in Sudbury, Ontario. "It will be the better part of a year before we can summarize and present our initial data." Scientists are hopeful that SNO will resolve one of the most enduring and perplexing mysteries in astrophysics: why the sun appears to be producing less than half the neutrinos predicted by theory.

Neutrinos are the ghostly messengers of the cosmos (see "Catching Cosmic Ghosts," June 1999). Billions of them pass through your body every second but do no harm. Neutrinos react so weakly with matter that the vast majority of them pass through Earth unmolested. The SNO is buried one mile beneath a nickel mine, a layer of Earth that absorbs almost every form of radiation except neutrinos.

The observatory's primary apparatus is a 240,000-gallon tank filled with heavy water and lined with light detectors. Heavy water looks like ordinary water but is rich in deuterium, a nonradioactive isotope of hydrogen that produces a tell-tale flash of light when hit by neutrinos.

Light sensors detected a faint burst of light when a neutrino hit a water molecule in the SNO.



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There are three types of neutrinos — muon, electron, and tau. Many physicists suspect that neutrinos produced by the sun could be oscillating from one type, or "flavor," to another as they travel toward Earth. The facility in Sudbury is the only neutrino observatory that can detect all three types of neutrinos, which may enable it to find neutrinos that would elude detection by other observatories. — **Robert Naeye**

STARSTRUCK

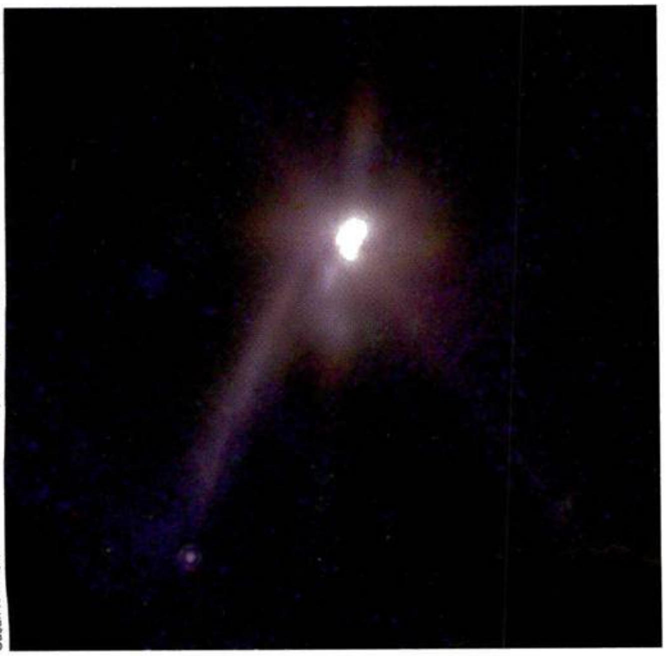
A Planet That's Probably Not

▶ "Hubble Space Telescope Images Planet Outside Our Solar System," trumpeted a May 1998 headline. If true, it would have amounted to the historic first direct observation of an extrasolar planet. But the discoverers, who issued a news release announcing their findings, have stopped talking to journalists amid suggestions by fellow astronomers that the curious object in the constellation Taurus is really a background star.

The faint, reddish "planet" in question appeared to be connected by a long dusty tendril to a pair of much brighter stars closely orbiting one another. However, skeptical astronomers were less convinced of the object's planetary status. They challenged discoverer Susan Terebey of the Extrasolar Research Corporation in Pasadena, California, and her colleagues to obtain a spectrum of the object, which could distinguish a planet from a star.

The parent star is cataloged as Taurus Molecular Ring star 1 (TMR-1), and the suspected planet is cataloged as TMR-1C. Astronomers said that the object could be dimmer than the two "parent" stars because it is farther away. It also could have a reddish color because of the effect of dust, an effect that would be more pronounced if it were farther away than TMR-1.

This young double star about 450 light-years away in Taurus lies embedded in a dust cloud that formed it. The faint object (lower left) was first thought to be an associated planet, but its high temperature suggests it is a more distant star.



Susan Terebey (Extrasolar Research Corp.), et al., and NASA

The need for a spectrum to try to settle the matter seemed reasonable to the director of the 10-meter Keck I Telescope in Hawaii. He granted some of his discretionary time to Terebey to take a spectrum.

When Terebey separated the light coming from the possible planet into its component wavelengths, the bar-code pattern of lines in the spectrum carried important clues about the object's chemistry and temperature. The Keck spectrum showed that TMR-1C is considerably hotter — likely hotter than about 2700° C (4900° F) — than would be expected for a planet.

Astronomers voiced more skepticism over Terebey's results during two recent scientific meetings. The high temperature was difficult to reconcile with any kind of a planetary body. "None of the substellar mass objects on the theoretical curves ever get that hot," says Keith Noll of the Space Telescope Science Institute in Baltimore. "So you have to find other special circumstances that allow this thing to be hotter than a planetary-mass object should be. At that point, I think you've left the realm of reasonable speculation. If, on the contrary, you assume this is a normal, distant star that is reddened, it is not very extraordinary. We find stars all over the place." — **Andrea Gianopoulos**

HALE-BOPP

First Comet Shadow Found Accidentally

▶ An unexpected blemish on a computer screen led to the serendipitous discovery in June of a comet shadow — the first such discovery. At the time, French astronomy graduate student Elisabeth Lamassoure was routinely analyzing ultraviolet (UV) emissions of hydrogen gas near the sun when the shadow appeared.

Of course, other sun-induced shadows are well known in the solar system: The moon's shadow produces solar eclipses on Earth; Earth's shadow creates lunar eclipses; Saturn's shadow is cast on its rings; and the four largest satellites of Jupiter — Io, Europa, Ganymede, and Callisto — cast shadows on the turbulent jovian surface. However, nobody had ever seen a comet's shadow.

"I'm not sure anybody ever thought of it," says Paul Feldman, chair of the Physics and Astronomy Department at Johns Hopkins University in Baltimore, Maryland.

Like an electric light surrounded by fog, the sun's radiation induces hydrogen atoms streaming through the solar system in the interstellar wind to emit UV light, so-called Lyman alpha emission. In June 1999, Lamassoure wrote a computer program to find small variations in Lyman alpha emission near the sun as an indirect way of detecting sunspots on the sun's far-side. She was working under

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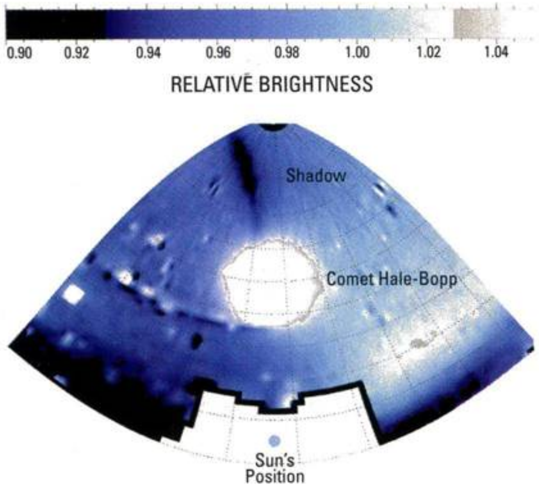

Jean-Loup Bertraux, ESA, SOHO

Comet Hale-Bopp casts an ultraviolet shadow more than 94 million miles (150 million km) long in this enhanced image.

the supervision of Jean-Loup Bertraux of the Service d'Aeronomie in Paris.

Bertraux's team had earlier collected UV data in March, April, and May 1997 with an instrument called SWAN (short for Solar Wind Anisotrophies) aboard the Solar and Heliospheric Observatory (SOHO).

SOHO and its 12 instruments, including SWAN, were designed to study the sun, not comets such as Hale-Bopp, which coincidentally was approaching the sun at the time. Bertraux regarded Hale-Bopp, a big white Lyman alpha blob in his group's UV images, as "a nuisance."

However, as he looked at his graduate student's computer screen one day in June, he was immediately mystified. "In the enhanced image on the computer screen, I noticed a faint depression of the Lyman alpha intensity," says Bertraux. He suspected that some sort of an instrumental artifact caused the dark smudge. "I went home and described it to my wife (astronomer and fellow team member Rosine Lallement). She instantly replied, 'It is the shadow of a comet.' "

Michael Combi, an astronomer at the University of Michigan and an expert on cometary physics who examined the Bertraux's data, agrees: "It's one of those things that you think about afterward that you should have thought would happen."

The shadow became much more than a curiosity. Combi had earlier estimated that, based on Hale-Bopp's brightness, the comet was producing about 330 tons of water vapor and dust per second. Combi's calculations based on the depth of the shadow confirmed his earlier vapor-production estimate.

LARGE MAGELLANIC CLOUD

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THIS CONTORTED CLOUD OF GAS AND DUST, NEBULA 44, was thrown off by a dying star and lies in the Large Magellanic Cloud (LMC). The LMC is a satellite galaxy to our Milky Way Galaxy about 170,000 light-years away and visible in the southern sky. The turbulent red pattern of the nebula traces the distribution of hydrogen atoms that have each lost one or more electrons due to the action of energetic ultraviolet radiation emitted by very hot, luminous stars nearby. The foreground and background stars exhibit various colors, indicating the temperature of the hottest (blue) to the coolest (red). Astronomers used the European Southern Observatory's 2.2-meter telescope at the La Silla Observatory in Chile, with its digital Wide Field Imager, to take the picture.

TELESCOPE TARGETS

Asteroid Hunt Intensifying

▶ Is astronomy beginning to imitate art?

The scientific competition to discover big, near-Earth asteroids has become so intense that it resembles last summer's movie box-office battle between *Armageddon* and *Deep Impact.*

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inch (1.2 m) Schmidt telescope and devote it to a full-time, automated search. "I think it would be the premier telescope in the world for asteroid searches," says Steven Pravdo, NEAT project manager at the Jet Propulsion Laboratory. Currently, the NEAT team uses a 48-inch automated telescope atop Mt. Haleakela on Maui, Hawaii, which is operated by the U.S. Air Force.

Meanwhile, the Massachusetts Institute of Technology's Lincoln Laboratory and the Air Force have added a second 39-inch (1 m) asteroid-hunting telescope at White Sands Missile Range in New Mexico. Grant Stokes, an astrophysicist who runs the Lincoln Near-Earth Asteroid Research (LINEAR) search, says his pair of scopes will blanket the sky, which could essentially preempt discoveries by other asteroid-hunting programs. Indeed, a single LINEAR scope found 41 of the 58 dangerous, kilometer-size near-Earth asteroids detected in the past year, according to the Minor Planet Center (MPC) in Cambridge, Massachusetts.

The Spacewatch program operating from Kitt Peak in Arizona and 18 other programs around the globe have discovered at least 100 asteroids each, according to the MPC. But NEAT and LINEAR are expected to dominate asteroid hunting in the future.

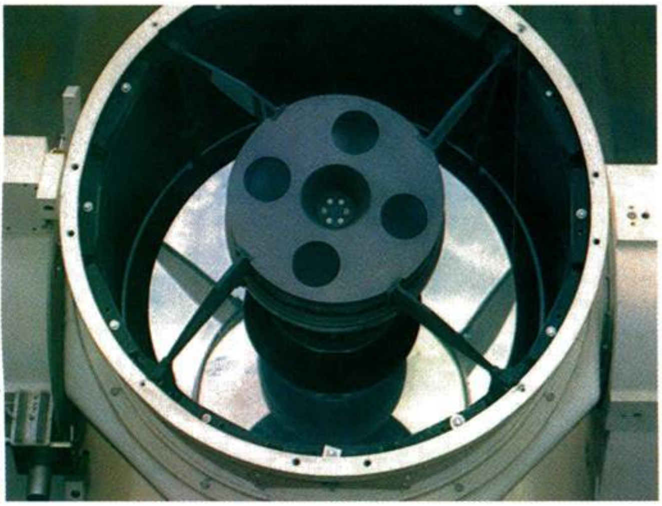
"The challenge is to balance the competitive nature of these folks and optimize the entire search," says Don Yeomans, manager of NASA's Near Earth Objects Office. "If LINEAR could pull back from searching the whole sky at 19th magnitude, it could search half the sky to 21st magnitude and Palomar could do the other half to 21st magnitude. That would be something."

Scientists estimate there may be 2,000 asteroids larger than 0.6 mile (1 km) that come within 30 million miles (48 million km) of Earth. Only 20 percent have been detected. NASA hopes to find the rest in 10 years.

LINEAR's CCD detectors, developed for tracking man-made objects in orbit, are more sensitive than NEAT's. However, Pravdo says NEAT is working with astrophysicists from Yale University on new detectors that would further enhance the search from Palomar Mountain.

It's a long way from the 1970s and 1980s when astronomers Eleanor Helin at Palomar and Carolyn Shoemaker at the Lowell Observatory in Flagstaff, Arizona, photographed the sky on thousands of glass plates. They painstakingly searched pairs of images for the telltale movement of asteroids amid a blizzard of background stars.

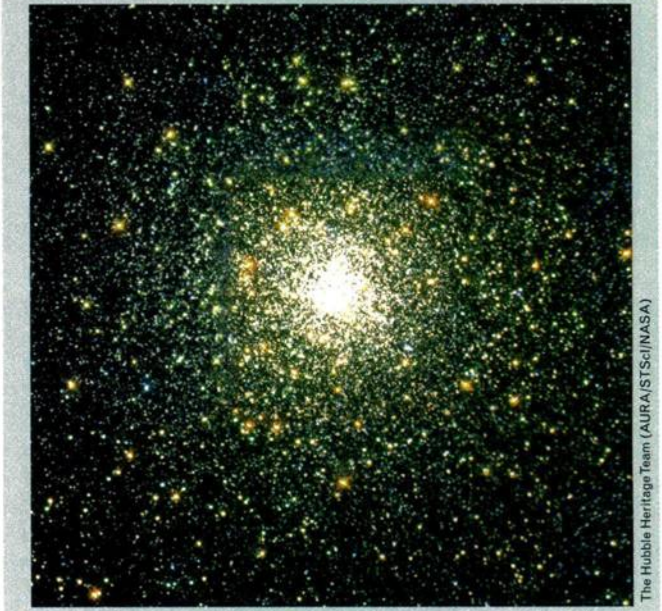
— David Graham



Lincoln Laboratory

MIT's Lincoln Laboratory and the Air Force have added a twin of this 39-inch (1 m) asteroid-hunting telescope, and Palomar Observatory is spending up to $500,000 to renovate its 48-inch (1.2 m) Schmidt telescope.

GLOBULAR CLUSTERS



The Hubble Heritage Team (AURA/STScI/NASA)

M80 (NGC 6093), ONE OF THE DENSEST KNOWN CLUSTERS in the Milky Way Galaxy, packs hundreds of thousands of stars together tighter than commuters on a subway. Collisions are common in the cramped conditions. The mergers of two stars generate massive, young-looking residents of the core called "blue stragglers." The high number of blue stragglers in this image taken by the Hubble Space Telescope suggests that the collision rate in the core of M80 is much higher than in other clusters. However, novae, explosions which result from the transfer of fuel from a star to a companion white dwarf, are less frequent than expected in such a dense cluster. Astronomers are studying M80 in an effort to explain the unexpected contradiction.

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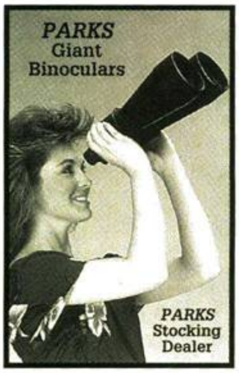

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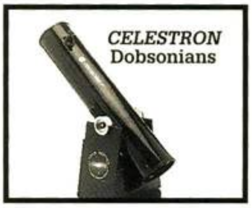

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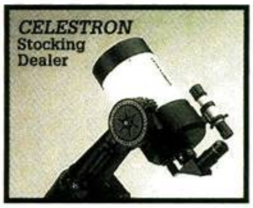

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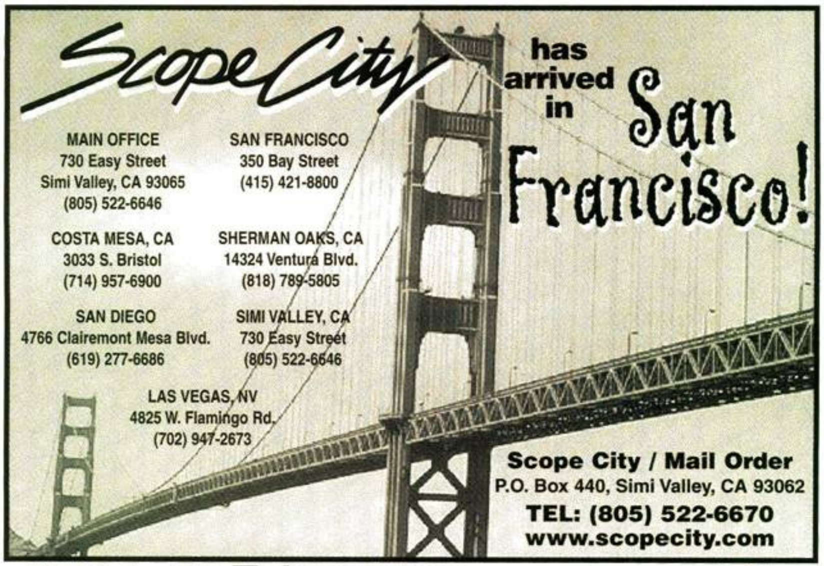

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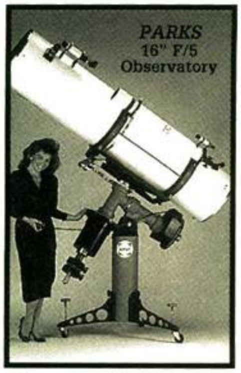

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Hale Telescope at the Palomar Observatory in California reigned as the world's most powerful optical telescope for 45 years. That crown was taken by the first of a pair of 10-meter Keck telescopes at Mauna Kea, Hawaii, when it began collecting starlight in 1993. With history in mind, most astronomers undoubtedly expected the mirror size of the largest optical telescopes to continue to double every 40 years or so.

However, telescope designers say telescope sizes will increase much faster in the future. "I don't know where the limit is," says Keck director Jerry Nelson. Ground-based-telescope developers attending a June workshop on Extremely Large Telescopes in Bäckaskog, Sweden, displayed designs that would increase the maximum size of telescope mirrors by factors of three, five, or even 10 — all within only two decades.

A team of astronomers from the National Optical Astronomy Observatories presented a design at the workshop for a relatively cheap and simple 35-meter (1,378 in) telescope. The plan is modeled after the 9-meter (354 in) primary mirror of the Hobby-Eberly Telescope at McDonald Observatory in Texas. A team of experts from Lund University in Sweden presented a scale-model of a 50-meter-diameter (1,968 in) "mega-Keck."

To top the Swedish plan, astronomers of the European Southern Observatory (ESO) presented detailed design studies for a 100-meter (3,937 in) design, the OverWhelmingly Large (OWL) telescope. The ESO team says the OWL telescope could be completed in 16 years for $900 million.

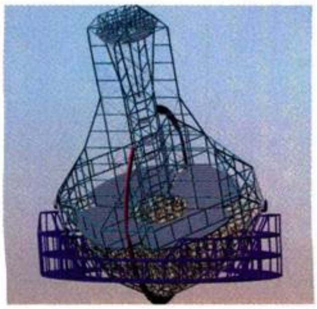
According to project leader Roberto Gilmozzi, the OWL mirror would consist of some 2,000 2.2-meter (87 in) hexagonal segments, kept in alignment by 500,000 computer-controlled actuators. "Computing power seems to be the biggest problem," says Gilmozzi.

The main advantage of such huge telescopes over space-based telescopes is their relatively inexpensive price. However, the costs of building space telescopes have fallen since the $2-billion Hubble Space Telescope began taking images in 1994 with its refurbished optics.

In the long run, the costs to build giant space telescopes are expected to actually become cheaper per square meter of polished mirror surface than the largest ground-based telescopes, says astrophysicist and telescope expert Neville Woolf of the University of Arizona. Woolf's group designs and builds ultralight optics for large-aperture telescopes intended to operate in the near-weightlessness of space. As unlikely as it may sound to some astronomers, Woolf says that even a 0.6-mile (1-km) space telescope could be built in the future.

— Govert Schilling

Artist's rendering of the 100-meter (3,937 in) OverWhelmingly Large (OWL) telescope, whose estimated cost is $900 million.



ESO

NASA's Star Wars Technology

The latest *Star Wars* movie, *Episode I: The Phantom Menace* flashes dozens of futuristic concepts past viewer's eyes. However, NASA is conducting research to try to make some of the technology in the movie a reality, and some might be closer than you think. For example, while NASA's aerogel won't stop enemy blasters or death rays, the agency has already used "frozen smoke" to help the Rover Sojourner stay warm on Mars. For more, go to http://www.astronomy.com/horizon.html.

Aerogel shields protect Gungan troops under attack. Lucasfilm Ltd., all rights reserved, used under authorization

Cable-Car Collapse Kills 20 Telescope Workers

Five scientists and 15 construction workers and technicians working at the Plateau de Bure Observatory south of Grenoble in the French Alps died July 1 when a cable car transporting them to the mountaintop observatory fell 260 feet (80 m). "At present, there is no explanation as to why this accident could happen," says a statement released by the Institut de Radio Astronomie Millimétrique (IRAM), which operates the radio observatory. "For IRAM and its partner organizations it is absolutely essential that the cause of this terrible accident be found as soon as possible." For more, go to http://www.astronomy.com/horizon.html.

Stellafane Light-Pollution Battle Continues

Amateur astronomers who gather annually for the telescope-building meeting at Stellafane suffered a setback on June 29 when voters in Springfield, Vermont, narrowly approved a plan to build a state prison nearby. Light pollution from the 350-bed, medium-security prison could seriously harm the heavenly views at the "shrine to the stars." However, a Springfield selectman has collected more than the 5 percent of registered voters' signatures required to force a revote on the issue. The next balloting could take place later this year. For more, go to http://www.astronomy.com/horizon.html.

Stellafane attracts more than 2,000 visitors each year. Stellafane

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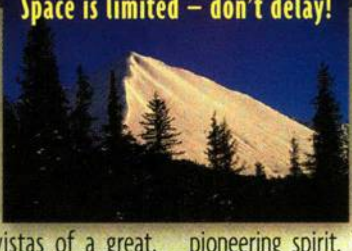

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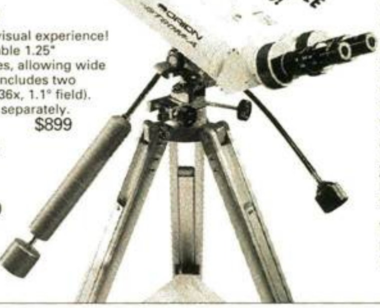

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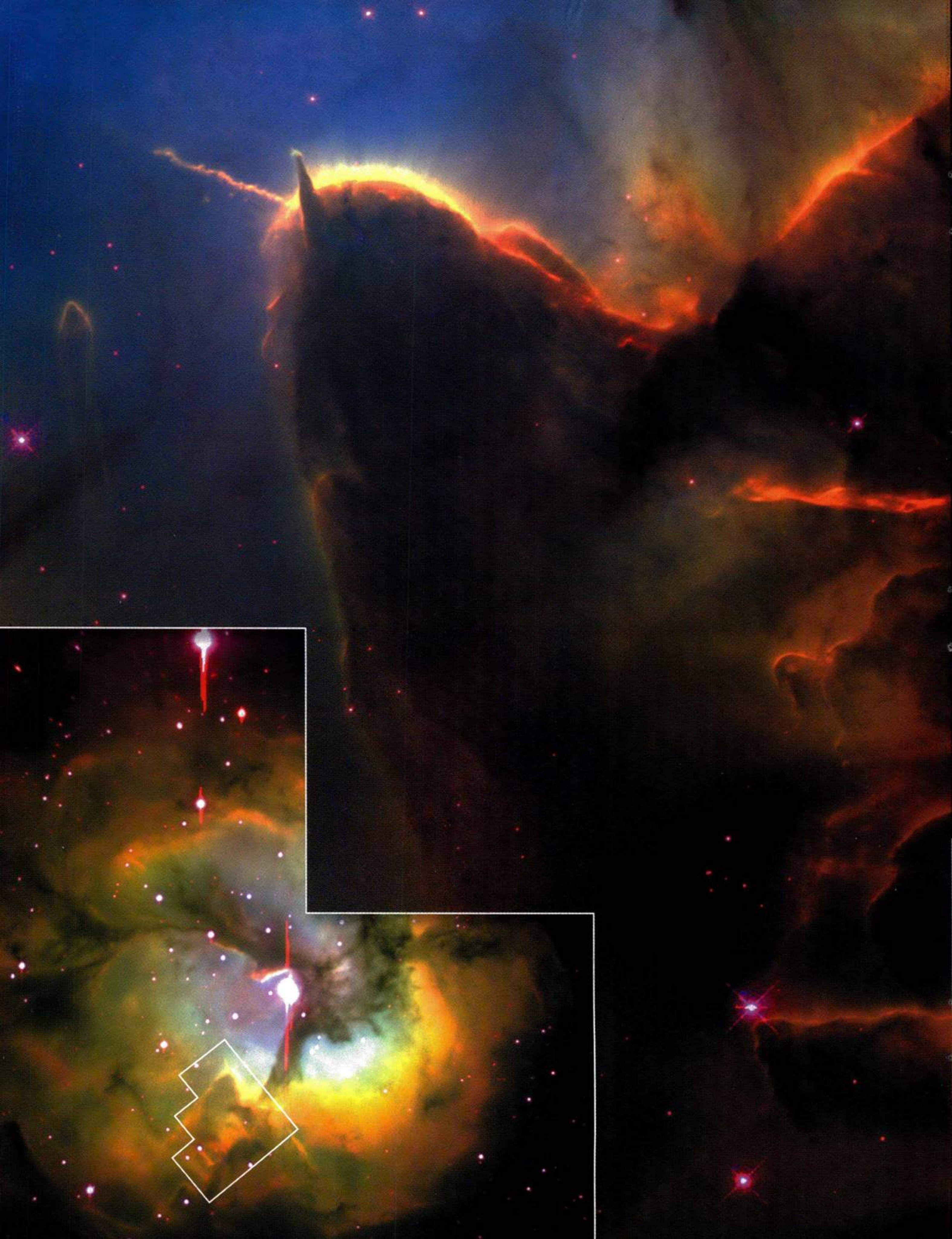


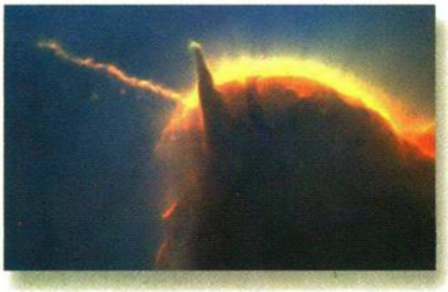
BACK TO THE FUTURE

While NASA officials look ahead, Hubble continues to astonish.

On June 3, 1999, NASA administrator Daniel Goldin told a convention of astronomers that they should be thinking about the telescopes of the future — Hubble's successor and Hubble's successor's successor. "Too many of you are hugging the Hubble Space Telescope," said Goldin. "HST is not your most important telescope today. And neither is the Keck, Gemini, or the Next Generation Space Telescope. No, for the torchbearers among you, your most important telescope must always be the one *after* the one you are dreaming about now: the telescope beyond your dreams."

Goldin envisions giant mirror arrays in space that can image oceans and continents on life-bearing planets orbiting other stars, providing children with maps of distant worlds that rival those of Earth that he studied in grade school. But in the meantime, we'll just have to make do with Hubble. It isn't boggling our minds with pictures of exotic alien landmasses, but nearly halfway through its 20-year mission, it continues to return dazzling images of everything in the cosmic menagerie from solar system objects to far-flung galaxies.

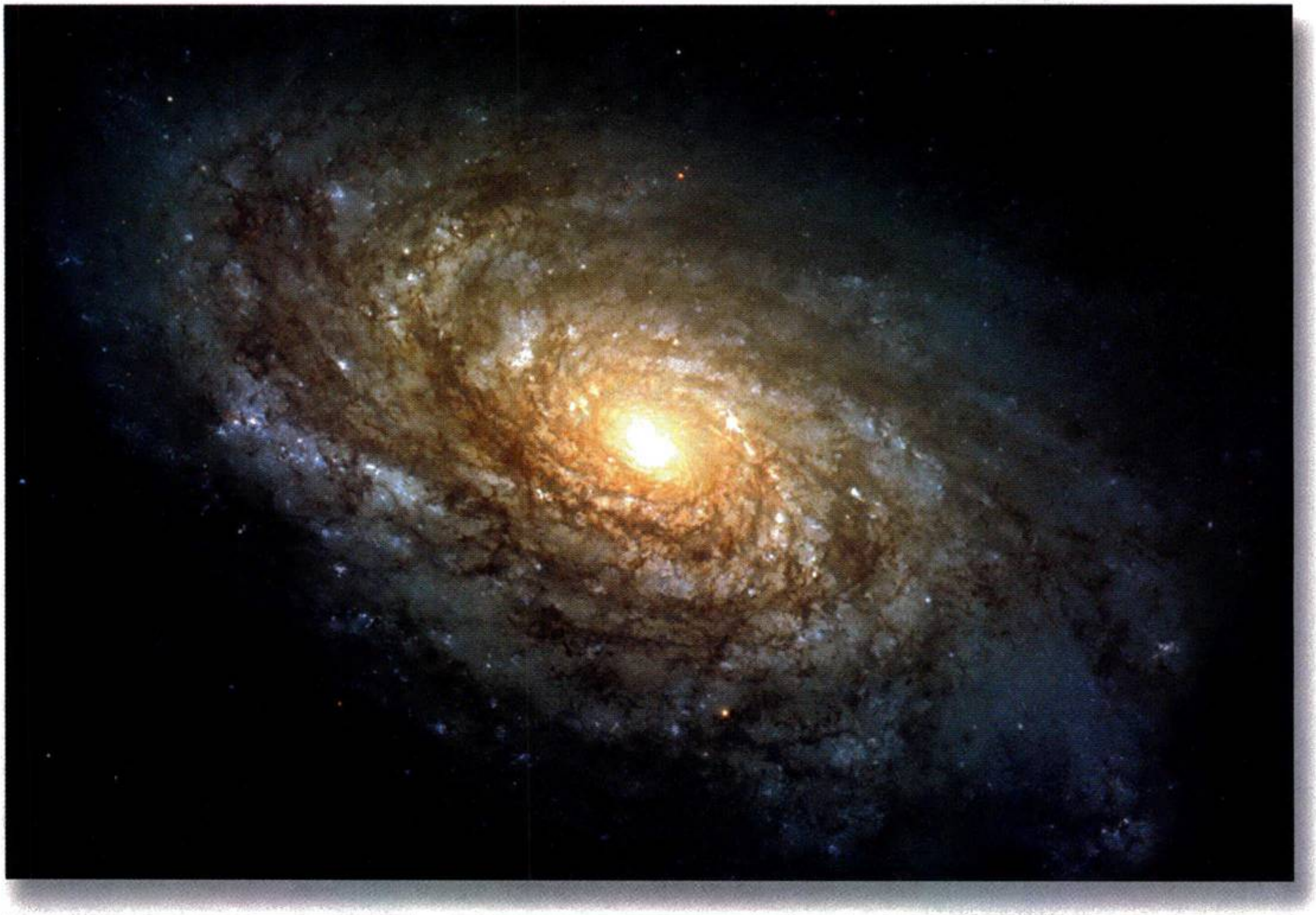
The latest batch of Hubble images carries on the telescope's tradition of versatility. The images show remarkable details in stellar nurseries, stellar death shrouds, and a galaxy 60 million light-years away. If the telescope beyond our dreams can top this, it will be a magnificent future indeed. — *Robert Naeye*



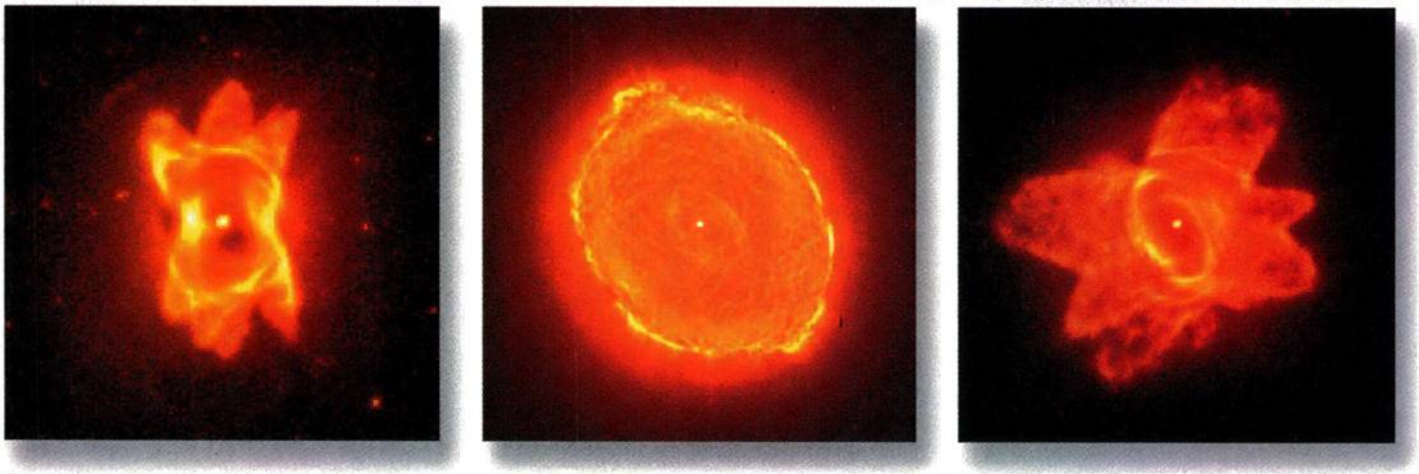
In this detail from the main image, a ¾-light-year long jet (left) is poking out of the main pillar. The jet, which abruptly turned on 600 years earlier, emanates from a young star embedded in the pillar. The "finger" of gas protruding just to the right of the jet probably contains a young star at its tip. Jeff Hester, Paul Scowen (Arizona State University), et al., and NASA

Left: Hubble's Wide Field/Planetary Camera 2 zooms in on a 6-light-year-wide portion of the Trifid Nebula (M20) to reveal a large, gaseous pillar nearly identical to the pillars of the Eagle Nebula (M16). The Trifid's central star lies 8 light-years away, off the top edge of the image. This massive, powerful star zaps the pillar with a tremendous dose of ultraviolet radiation, slowly eroding it to nothingness. This "photoevaporation" process may both trigger the formation of new stars inside the pillar as well as deprive those stars of material before they reach maturity. Jeff Hester, Paul Scowen (Arizona State University), et al., and NASA

Bottom left: This ground-based image shows the Trifid Nebula, 9,000 light-years away in Sagittarius. The Hubble field is boxed. Jeff Hester (Arizona State University) and Palomar Observatory



Top: By observing pulsating, luminous stars called Cepheid variables, astronomers on the Hubble Space Telescope Key Project team determined that this galaxy, NGC 4414 in the constellation Coma Berenices, lies about 60 million light-years away. The galaxy is similar to the Milky Way in size. Like most spiral galaxies, the central bulge contains mostly older, yellow stars while the spiral arms contain young, blue stars. The arms also contain clouds of dark interstellar dust, which mark areas of ongoing star formation. Hubble Heritage Team (AURA/STScI/NASA)



Above: These false-color images show planetary nebulae, the gaseous death shrouds of ordinary stars. The nebulae display a remarkable degree of point symmetry, meaning a feature on one side has a corresponding feature on the exact opposite side of the dying central star. High-speed jets of hot gas appear to be carving out the complex yet symmetric shapes of these nebulae. Although controversial, some astronomers think these jets arise from the presence of substellar companions such as planets and brown dwarfs. Raghvendra Sahai, John Trauger (JPL/Caltech), and NASA

Right: Hubble resolves a 2-light-year-wide cloud of hot gas for the first time. The cloud is named the Papillon Nebula ("papillon" is French for "butterfly"). The butterfly shape originates from a powerful outflow of gas from a massive young star embedded in the nebula. Mohammad Heydari-Malayeri (Paris Observatory), et al., and NASA/ESA

Left: Hubble's Wide Field/Planetary Camera 2 images a turbulent region of star formation in the Large Magellanic Cloud, a small galaxy 170,000 light-years away. This region, known as N159, is 150 light-years across. In this true color image, we can see powerful winds from young stars sweeping the surrounding gas into arcs and filaments. The bright clump is shown at higher resolution above.

Mohammad Heydari-Malayeri (Paris Observatory), et al., and NASA/ESA

Accelerating the Cosmos

Cosmologists have discovered a new kind of energy that is speeding up the universe's expansion.

by James Glanz

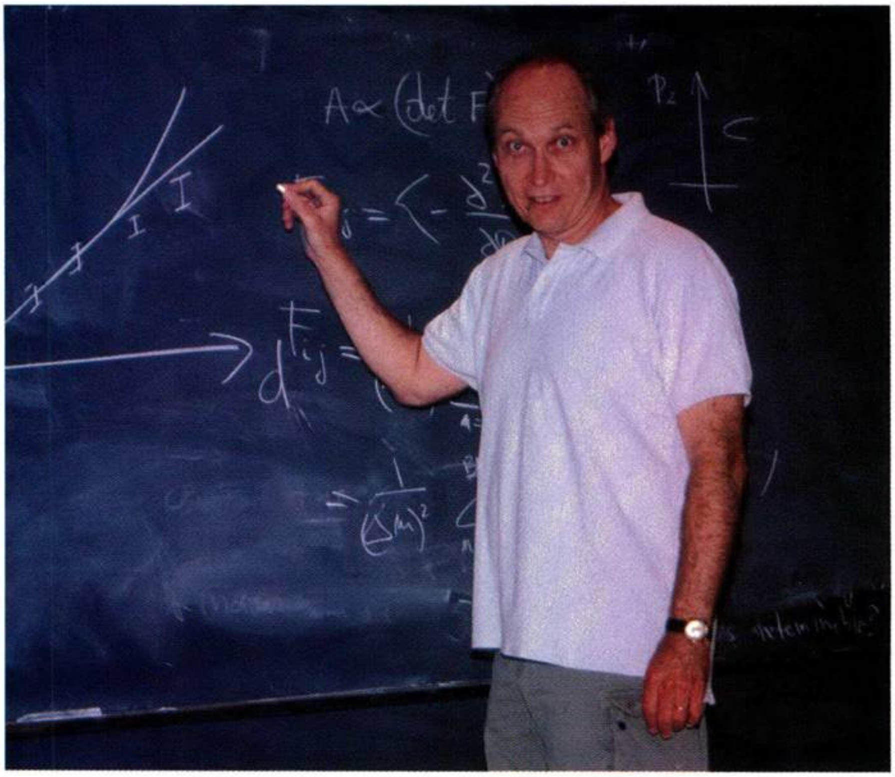
There are times — very rare ones — when a journalist feels that he or she has been lucky enough to see the making of great science through a helmet cam. These miniature videocameras, mounted in the helmets of football running backs and baseball catchers, often reveal balls and bodies tumbling through the field of view, followed by huge grasping hands or approaching shoulder pads. The video image wobbles crazily before slamming to a stop against a piece of chewed-up turf.

I write about physics and astronomy for *Science* and my view of the discovery of the cosmological constant over the last two years has been as jarring as any athlete's in the heat of competition. The discovery, which astronomers made by observing the apparent brightness of distant, exploding stars called supernovae, has shaken astronomy to its core. Indeed, the discovery of the cosmological constant looks like one of the more important developments in any field of science in the 20th century.

Lawrence Berkeley National Laboratory's Saul Perlmutter and his colleagues used supernovae such as 1987A, background, to look for expansion much deeper in the universe.

Roy Kaltschmidt (Lawrence Berkeley National Laboratory)

The research leading up to the discovery has been no humdrum, two-yard dive into the line. As the results accumulated over the past year and a half, I have been carried along on the equivalent of a breathtaking open-field touchdown run, complete with stiff-arms, head jukes, and 360-degree spins. The helmet cam's audio has picked up the approving and disapproving roars from the scientific crowd on the field and the sidelines.



Felicia DeHerrera

University of Chicago cosmologist Michael Turner predicted several years ago that the cosmological constant might one day be found. He also calls it "funny energy."

Space's Springiness

The cosmological constant, also called lambda (Λ), is a uniform, background energy permeating all of space. This energy gives space itself a sort of springiness, counteracting gravity on large scales — billions of light-years in a universe that is probably less than 14 billion years old. It is because this background energy is so tenuous in space that it takes such great distances to amount to much. Gravitating mass collects in stars, galaxies, and clusters of galaxies, while lambda remains spread out in its battle against gravity. If this stuff sounds very strange, don't be alarmed — everyone agrees that it is.

"This astounding result doesn't seem to be willing to go away quietly," said Adam Riess of the University of California, Berkeley. Riess is an important player on the High-z Supernova Search Team, one of two independent, international groups of astronomers who, beginning in about January of last year, began to see evidence of a cosmological constant. Both teams frantically re-examined their data in search of some mistake. At the time, Riess gave me a two-word answer when I asked him to describe his group's mood as it became clear that the data were indeed solid: "Stunned, stunned."

What came to mind then was the view from a minicam as tacklers lunge at a football player who, although jostled wildly, somehow keeps his feet and runs for a touchdown. But if the High-z Team and a companion group, the Supernova Cosmology Project, found the race for the cosmological constant disorienting, they had good company. Albert Einstein had first introduced a lambda term into his equations of general relativity in 1917. Later he changed his mind, calling the cosmological constant "my biggest blunder."

Nevertheless, the idea refused to die, enjoying periodic revivals punctuated by decades of obscurity until the spectacular developments of last year. Lambda makes itself felt in the expansion of the universe, which is thought to have begun with the explosion of a point of nearly infinite density, the Big Bang. Gravity should act like a brake, slowing this expansion as each wisp of gas, dust cloud, and galaxy in the universe attracts other wisps of gas, dust clouds, and galaxies. For that reason, the universe's expansion should slow: The rate of deceleration would provide a gauge of the total amount of matter in the universe — reason enough for astronomers to measure it. The action of a cosmological constant, however, would counteract the slowdown, boosting the expansion.

An Unexpected Discovery

Within our local cosmic neighborhood, where we see only a fragment of the universe, the expansion rate is nearly constant. Astronomers estimate that rate by measuring the apparent brightness, as seen from Earth, of special stars whose brightness is known. These stars appear dimmer the farther their host galaxies lie away from us. Astronomers measure the local expansion rate by comparing the star-Earth distances with the speed at which each star moves away from us. That rate is called the Hubble constant. However, to find out how the expansion has changed over billions of years, astronomers needed brighter objects, which could be seen from much farther away. They turned to what Alexei Filippenko of the University of California, Berkeley and the High-z Team calls "these wonderful bombs that nature has given us": type Ia supernovae.

Not only are the type Ia objects the brightest type of supernova, but each explodes with roughly the same brightness. Residual differences can be accounted for, since brighter ones take longer to fade away. The fading allows astronomers "to read the wattage of the light bulb" on this new and more powerful distance gauge, says Filippenko.

A funny thing happened while astronomers began measuring the change in the expansion rate. It came as a shock, as if a blitzing football linebacker appeared out of the blue: The expansion was not slowing down after all. In fact, it was speeding up. When Einstein's equivalence formula $E=mc^2$ was applied, the universe appeared to contain twice as much energy in the cosmological constant as it did in matter. POW.

Thunderstruck astronomers recovered quickly. In recent months, they have been extending their measurements still farther: They have been tackling more distant supernovae and searching for any effect other than cosmic acceleration that could account for their findings. So far, they have found no reason to doubt their conclusions. Since the discovery is so unexpected, so important, and so heretical, the intense scrutiny will surely continue — exactly as it should in scientific research.

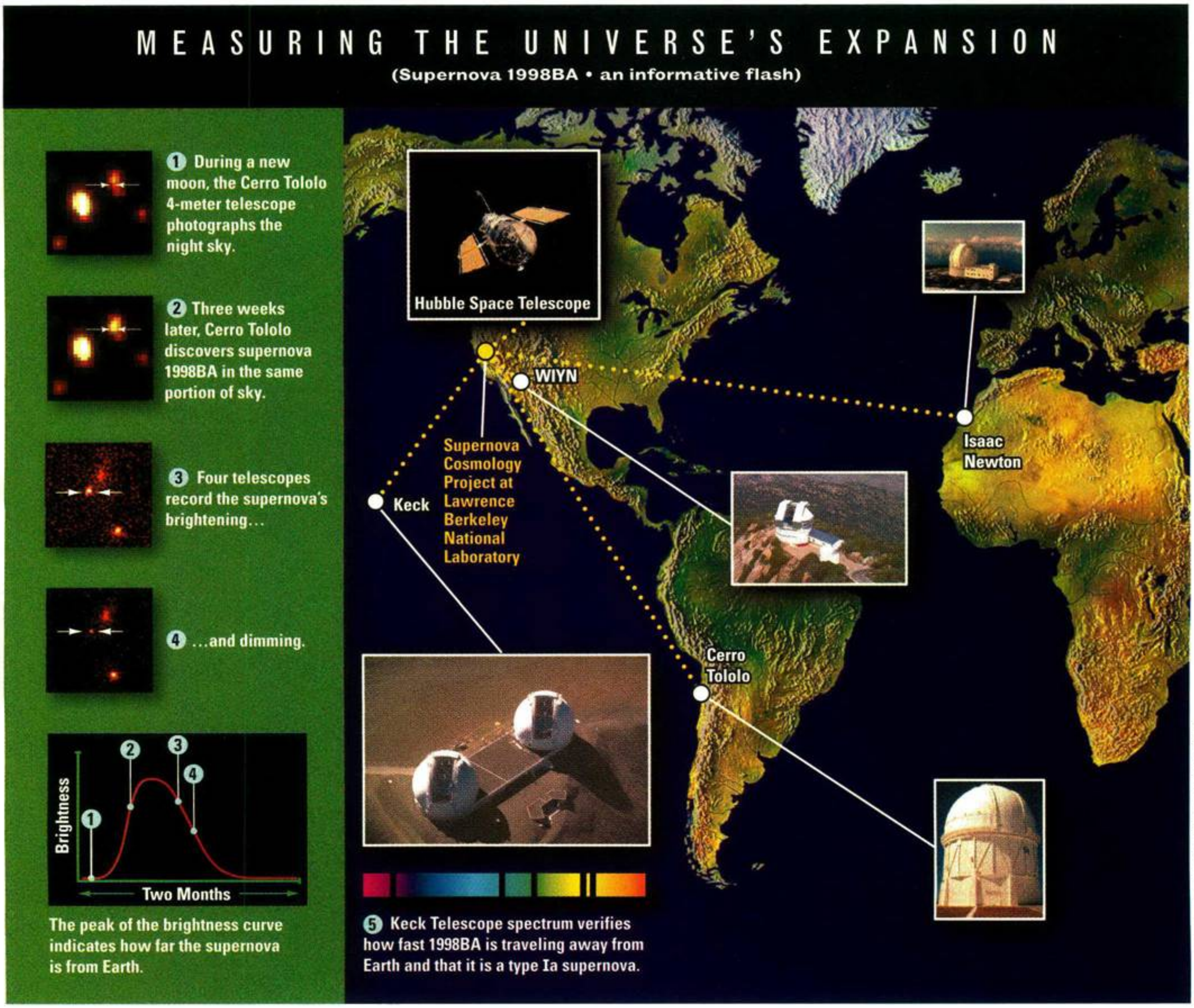
Cosmology Solved?

At the same time, particle physicists are studying the structure of space to determine just what lambda might be. Its source remains mysterious as new ideas about its nature proliferate. Cosmologists are perhaps the happiest group of all with the sudden change. One of them is Michael Turner of the University of Chicago. He refers to the cosmological constant as "funny energy." The amounts of it suggested by the new work could be just enough to square many different observations with inflation theory, the leading theory describing the first moment of the universe.

In fact, several years ago, before the supernova results even appeared, Turner and a handful of others had the audacity to suggest that a cosmological constant might someday be found. Last fall, Turner, in effect, exuberantly spiked the football and did a little touchdown dance during a talk in Washington, D.C., as he described how all known observations now fall into place with theory. The talk was entitled "Cosmology Solved? Quite Possibly!"

Einstein kicked off this astronomical contest in 1917. That was two years after he had formulated his theory of general relativity, showing how gravity bends space and moves matter around on large scales. Astronomers of the day thought the universe was static — neither expanding nor contracting. But when Einstein applied his relativity equations to the entire universe, he couldn't find a static solution. Failing to do so, he introduced the cosmological constant to prevent gravity from smooshing everything together and

Scientists with the Supernova Cosmology Project take images of tens of thousands of galaxies during new moon, when the night sky is dark. A few weeks later they observe the same regions of sky and electronically subtract pairs of images from one another. Brightening supernovae leap out when the two sets of images are compared. Cooperating telescopes that are part of a companion group, the Supernova Cosmology Project, follow the rise and fall of each supernova's "light curve." The peak brightness of each supernova, as seen from Earth, is a measure of its distance.



MEASURING THE UNIVERSE'S EXPANSION

(Supernova 1998BA • an informative flash)

① During a new moon, the Cerro Tololo 4-meter telescope photographs the night sky.

② Three weeks later, Cerro Tololo discovers supernova 1998BA in the same portion of sky.

③ Four telescopes record the supernova's brightening...

④ ...and dimming.

The peak of the brightness curve indicates how far the supernova is from Earth.

⑤ Keck Telescope spectrum verifies how fast 1998BA is traveling away from Earth and that it is a type Ia supernova.

Supernova Cosmology Project, *Astronomy*: Terri Field making a big mess. He soon regretted his fudge factor, which he symbolized as lambda in the equations.

In 1929, the astronomer Edwin Hubble announced the results of a detailed study of the distances and recession velocities of galaxies with stars called Cepheid variables. The regularity with which these stars fluctuate tells their absolute brightness, and the "redshift" of the host galaxy — an apparent lengthening of the wavelength of their light, like the drop in pitch of a receding train whistle — gives a gauge of the speed at which they are moving away from us. Hubble found that the farther away a star's host galaxy, the faster its recession, indicating a uniformly expanding universe.

A Constant With Varying Appeal

Expanding universes were permitted in Einstein's equations, either with or without a lambda, so Einstein discarded lambda as an unnecessary complication. From that moment on, theorists occasionally found the cosmological constant useful, but it somehow felt slightly illicit, like using too many players on a team. Lambda's popularity eventually waned altogether. "If you have learned cosmology anytime in the last 25 years, you probably learned it without the cosmological constant as part of the course," Saul Perlmutter of Lawrence Berkeley National Laboratory, who heads the Supernova Cosmology Project, said in a recent lecture on his team's results.

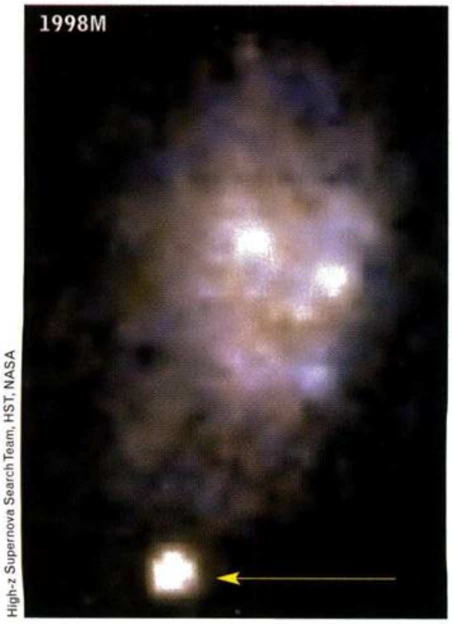
In the decades after Hubble's discovery, astronomers gradually realized that supernovae might let them look for expansion much deeper in the universe, beyond the realm of Cepheid measurements. Unfortunately, severe technical problems prevented astronomers from realizing that promise: Since type Ia supernovae go off only about twice per millennium in a typical spiral galaxy, how could astronomers ever observe enough of them to do cosmology? Surprisingly, the Cold War helped provide a solution.

Stirling Colgate, the brilliant and famously uninhibited physicist at Los Alamos National Laboratory, provided the first glimmer of an answer. In a 1979 paper titled "Supernovae as a Standard Candle for Cosmology," Colgate's idea was that robotic telescopes would continually scan the nocturnal skies for the transient brightenings of supernovae. When one turned up, astronomers would be automatically notified so that they could do follow-up observations of the events. Colgate once explained to me that his original inspiration for the robotic supernova search had nothing to do with cosmology. He said that in 1959, he was part of a team negotiating with the Soviet Union on satellites that would monitor atmospheric nuclear blasts from space by detecting the gamma rays that emerged from them.

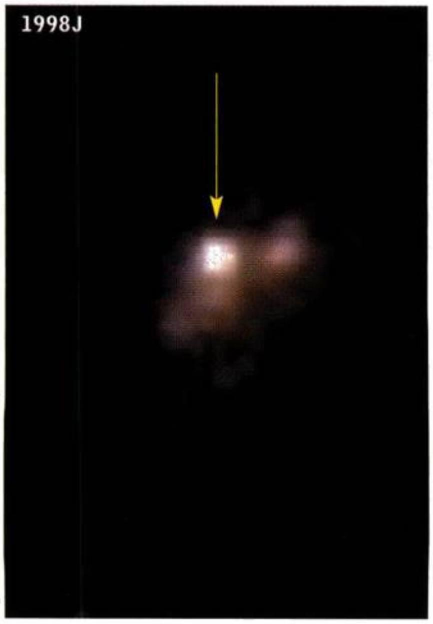
Eventually, the American Vela satellites were launched to detect the nuclear blasts, but Colgate said the Russians at first claimed that supernovae could cause false alarms. At the time, no one knew what a supernova would look like with such detectors. Colgate, the cold warrior, had an answer: "I said, 'You son of a bitch, I'll show you.'" Despite his laudable intentions, Colgate eventually realized that the computing power and electronic light detectors available at the time were not up to the robotic-telescope task.

Later a Danish group followed up on the general idea, flying back and forth between their home country and a telescope in South America. But after a period of many months, the Danish group had accumulated "a whole bunch of frequent-flyer miles and one supernova," says Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics and a member of the High-z Team. One supernova is not enough to do cosmology. Little changed until one day in 1987, when Perlmutter and Carl Pennypacker, then both graduate students at UC Berkeley, sat around trying to come up with ideas for new research directions. They wanted to find something that would help them declare intellectual independence from their mentor, Rich Muller, himself a protégé of Nobelist Luis Alvarez. By then, computers were more powerful, and charged-coupled devices — or CCDs, the light-sensitive chips that function as "electronic film" — were becoming larger and more reliable all the time.

Perlmutter was actually operating a robotic telescope to seek out nearby supernovae and search for a dim star that Muller and others had postulated might be in a highly elongated orbit around our sun with a period of 26 million years. Muller and others thought that the star could potentially



High-z Supernova Search Team, HST, NASA



High-z Supernova Search Team, HST, NASA

High-z Supernova Search Team, HST, NASA

disturb the Oort Cloud of comets that swarm around the solar system about 1 to 2 light-years from the sun. If that occurred, the star could cause some of the comets to rain down on the inner solar system and pummel Earth, resulting in an environmental catastrophe. Perlmutter never found the theorized death star. (He never disproved its existence, either: The project suffered from weak financial support.) However, the robotic telescope was able to identify 20 nearby supernovae.

Perlmutter and Pennypacker decided the time might be right to search for supernovae farther away — just as Colgate had envisioned. "Basically we took his idea and we updated it," says Perlmutter. "We called it the 'deep search.' The idea was to go out far enough that you could be relevant to the changes in the Hubble constant. That would be a deceleration parameter, as we thought."

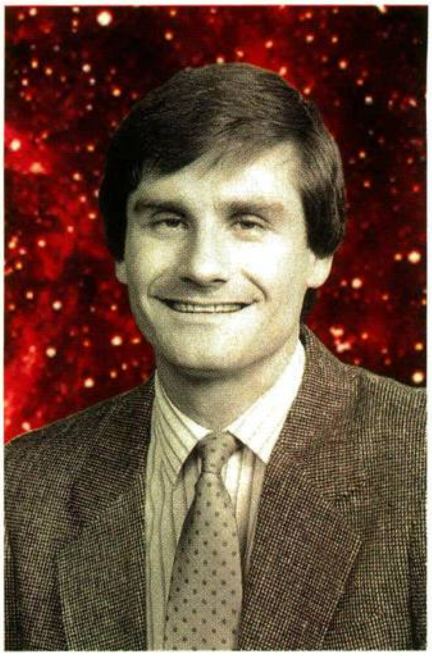
In this case, the great distances actually worked in their favor since even a small swatch of sky would contain swarms of the host galaxies. Moreover, the universe's expected deceleration could be studied without knowing the exact value of the Hubble constant itself, just as you can sense that a car is slowing down without looking at the speedometer. Ultimately Perlmutter and a growing list of cosmological teammates came up with a plan to observe tens of thousands of galaxies during new moon, when the night sky is dark. A few weeks after those observations, the same regions of sky would be observed and the two sets of images "subtracted" electronically on computers. A brightening supernova would leap out, allowing other telescopes to follow the rise and fall of its "light curve" and determine the peak brightness as seen from Earth.

Astronomical Culture Clash

Effective as this supernova search turned out to be, this wholesale method was seen as a thumb in the eye of the prevailing astronomy culture. Astronomers compete for time on top-notch telescopes and regard it as something precious, planning intensive observations of one or two objects of interest and learning everything possible about them. Perlmutter was talking about catching 40 or 50 supernovae and throwing the bad ones away. Such an approach was routine for particle physicists in the Alvarez group, but almost unthinkable for most other traditional astronomers.

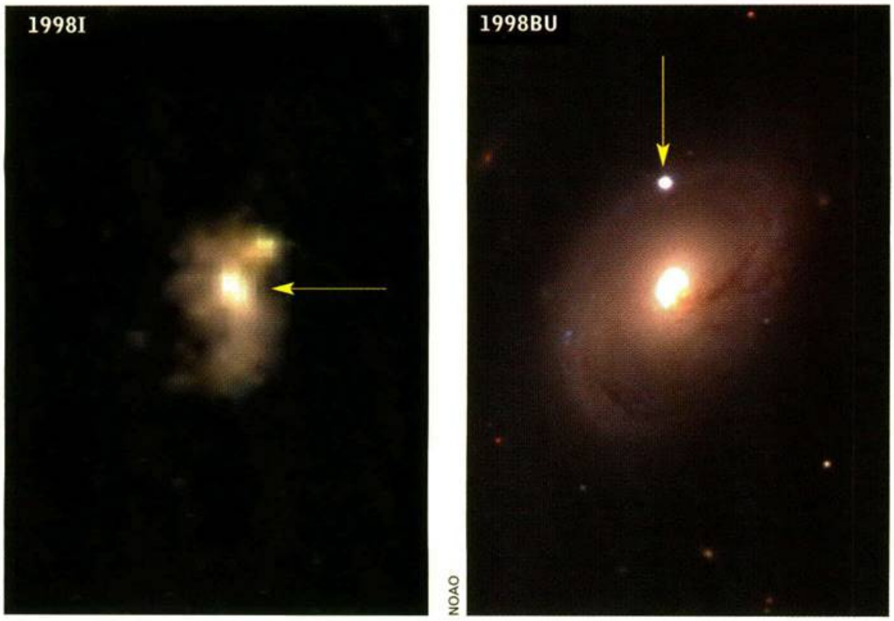
To make matters worse, the secretive and powerful scheduling committees on major telescopes were prepared to grant him random slots of free time; however, they didn't respect the rhythm needed for his research algorithm. "They had a long tradition of never telling anyone anything until it was all a fait accompli, until there was already a schedule written," said Perlmutter. "And at that point, they would never touch it, because they would be taking away someone's time and that person would really be angry. So we had to work our way into that sociology."

Perlmutter became friends with the schedulers of about half the major telescopes around the world. By 1994, the observations were in full swing. Meanwhile, the High-z Team formed and chose Brian Schmidt of the Mount Stromlo and Siding Spring Observatory in Australia as its leader. Schmidt had done his Ph.D. under Kirshner. Not coincidentally, developments elsewhere were making type Ia supernovae look like even better distance indicators. Mark Phillips of the Cerro Tololo Inter-American Observatory in Chile had completed a careful study of nearby type Ia supernovae and found that a slower rise and fall in the light curves indicated higher peak brightness, allowing for an even better read on the wattage of these brilliant "light bulbs."


Jane Scherr

Alexei Filippenko of UC Berkeley and the High-z Team calls type Ia supernovae "these wonderful bombs that nature has given us."

Why the brightness correlates to the rise and fall of a supernova's light output is not precisely understood. The explosions are thought to originate from a particular type of white-dwarf star — a dim, dense, stellar cinder made mostly of carbon and oxygen. Its strong gravity may gradually suck material from a companion star. Eventually, the growing white dwarf passes a threshold called the Chandrasekhar limit and begins to collapse under its own weight. In the collapse, the core heats rapidly, igniting a colossal thermonuclear explosion.



High-z Supernova Search Team, HST, NASA

NOAO

These are some of the type Ia supernovae that have helped astronomers calculate that the expansion of the universe is accelerating.

Jon Chase

High-z Team member Robert Kirschner notes that astronomers involved in prior supernova searches had scant luck.

Oddball Datum

Perlmutter's Supernova Cosmology Project actually found a few supernovae and the excitement soared. But there remained a few drastic reversals before the cosmological constant lit up the scientific scoreboard.

By the summer of 1995, Perlmutter's group had mostly completed the analysis for one distant supernova and had partially analyzed six more. (The light curves take weeks or months to rise and fall, and it can be a year before the astronomers obtain a final image of the host galaxy without a trace of supernova light, a necessary step in calibrating all the many previous telescope observations.)

One of those first supernovae, however, turned out later to be an "outlyer," a statistical oddball. "Their preliminary analysis of one supernova already casts doubt on a strongly accelerating expansion — the mark of a cosmological constant in a low-density universe," I wrote in *Science*. Almost exactly a year later, with those conclusions still regarded as preliminary, I was writing about a series of debates on the campus of Princeton University dealing with cosmological questions. In one Princeton debate, Turner, the Chicago theorist, was arguing for a position that then seemed unlikely, to put it mildly: He maintained that theoretical and observational evidence suggests that the universe has a low density of matter, which would favor the expansion of the universe. He also argued that the cosmological constant supplements the expansion. Turner conceded that if Perlmutter's early conclusions held up, this heretical view could not possibly be right. But in the most striking example of a theorist's hubris (and, as it turned out, foresight) I have ever witnessed, Turner warned Perlmutter that because the supernova results were still not definitive, they should not be presented during the Princeton debates.

At one point, a chattering crowd of astronomers and cosmologists were climbing a flight of stairs to an auditorium after a break in the action. Turner was a few steps below Perlmutter. I walked on one side of Turner, and on the other side walked astronomer Wendy Freedman of the Observatories of the Carnegie Institution of Washington. As if he were feigning to speak to Freedman, Turner raised his voice slightly in commenting on Perlmutter's plan to announce his preliminary results (I alter the language slightly for reasons of politeness): "I don't think Saul is that unenlightened." Perlmutter did not seem to hear. Turner then shouted: "I said I don't think SAUL is that UNENLIGHTENED."

Just to make sure no one missed the point, Turner gave another version of this admonition during his own talk. "I am anxiously awaiting the results of the two deep searches for supernovae," he said. "I think they're going to shed some important light on this. To draw any conclusion now would be to take away from their thunder later." For whatever reasons, Perlmutter didn't give his planned talk. The Supernova Cosmology Project did publish its results — and properly so, since the astronomical community deserved a chance to examine and comment on them. Nevertheless, the real thunder was coming.

The first observations were made from the ground, through the distorting confusion of Earth's atmosphere. By late the following year, not only had both groups refined their observing strategy from the ground — they had also made the leap into orbit. They won observing time on the Hubble Space Telescope. Acting on a tip, I wrote a story, published October 31, describing the first sketchy evidence from both groups that cosmic expansion did not seem to be decelerating at all. The cosmological constant was mentioned as a possible culprit, but that reasoning still seemed too strange to take seriously. In any event, the conclusions were still based on a mere handful of supernovae.

Fateful Conversation

The game changed radically at an American Astronomical Society meeting in Washington, D.C., in January 1998. The two groups scheduled a joint press conference in which — according to the press releases given out beforehand — they would formally present the results I wrote about the previous October. I skipped the press conference, thinking I had better things to do, but fortunately ran into Perlmutter later that day. We sat down at a table in the commons area of the conference. After a few minutes of conversation, he told me that he had presented new observations at the press conference: 42 supernovae. The data had not been fully analyzed yet. But there was some suggestion, he said, that there could be "a huge cosmological constant."

Bells started going off in my mind. I asked him to explain. On average, he said, the supernovae were dimmer than expected, implying that cosmic expansion has sped up. Perlmutter cautioned that the group was still correcting for possible dimming of the light by dust and that the conclusions could still change. But I folded my steno pad and hurried away in pursuit of another conference participant — the talkative Chicagoan, Turner.

"It would be a magical discovery," said Turner. "What it means is that there is some form of energy we don't understand" — the cosmological constant that he had defended in the Princeton debates. My report in *Science* came out on January 30. Out of the huge press contingent at the meeting, a few other publications — including the *San Francisco Chronicle*, *U.S. News & World Report* and *Astronomy* — also picked up on the importance of what Perlmutter was saying and reported it, usually in low-key fashion.

Things didn't really break loose until a month later when the High-z Team was about to announce the confirmation of the Perlmutter results at a small conference in Marina del Rey, California. The High-z Team had actually completed their dust corrections and the suggestion of a cosmological constant was, if anything, even stronger in their data. Working quietly, I interviewed cosmologists both inside and outside the team and wrote one of my most important stories. This time all of the major daily newspapers, news magazines, and electronic media picked up the story.

Soon, an unusual, but understandable, note arrived. It was from Brian Schmidt, the High-z Supernova Search Team leader: "My own reaction is somewhere between amazement and horror. Amazement, because I just did not expect this result, and horror in knowing that it will likely be disbelieved by a majority of astronomers — who, like myself, are extremely skeptical of the unexpected." His fear was initially borne out. During a lecture at the White House a short time later, Stephen Hawking, the University of Cambridge cosmologist, was asked about the new supernova results and he suggested that they were too preliminary to be taken very seriously. But throughout the rest of the year the results became stronger as fresh data came in and no one could find a flaw in the teams' analysis.

Breakthrough Story

In December 1998, *Science* named the accelerating universe the "Breakthrough of the Year." In March 1999, during a press conference at a meeting of the American Physical Society in Atlanta, I asked Hawking whether he had changed his mind. "I have now had more time to consider the observations, and they look quite good," Hawking said with his synthesized voice. "This led me to reconsider my theoretical prejudices. I now think it is very reasonable that there should be a cosmological constant."

Later, as I walked up to thank Hawking for fielding questions, Gerson Goldhaber appeared, looking distinctly pleased. He was one of the first members of the Supernova Cosmology Project to argue that the data supported a cosmological constant. He had been standing in the back of the room. He also wanted to thank Hawking. "I wouldn't say I think the evidence for a cosmological constant was cast iron, but it is as good as many things in cosmology," Hawking added. Not wishing to lose the quote, I reached for my steno pad, opened it and began scribbling while repeating the words as I remembered them, unsure whether I had it exactly right. Hawking kindly hit a button and replayed his comment on his synthesizer. I thanked him again.

The two groups have been busy since then. The Supernova Cosmology Project will soon have completed the analysis of 80 supernovae, while the High-z Team has analyzed about 40.

Both groups are currently in the midst of observing runs, with dozens more supernova discoveries expected. Ever more detailed examinations of both nearby and distant supernovae are under way to try to find any hint that they fall short as standard candles — a search that has so far been agreeably unsuccessful. Perlmutter has even proposed a dedicated satellite that would observe thousands of supernovae from space using new CCD technology developed at Lawrence Berkeley National Laboratory.

These days, I feel a bit drained by the cosmological constant story, as if I had lived through five Super Bowls — all with close scores — and a World Series or two. Although the observational case continues to strengthen, the importance of the discovery ensures that it will continue to be challenged at every turn — as it should be.

What physical entity is responsible for the constant? Nobody knows. The so-called "funny energy" could be anything from the evanescent particles that quantum mechanics says should pop in and out of existence to a weird, fluid-like substance called quintessence, a squishy possibility that might be pinned down with the vastly increased numbers of supernovae possible with the satellite.

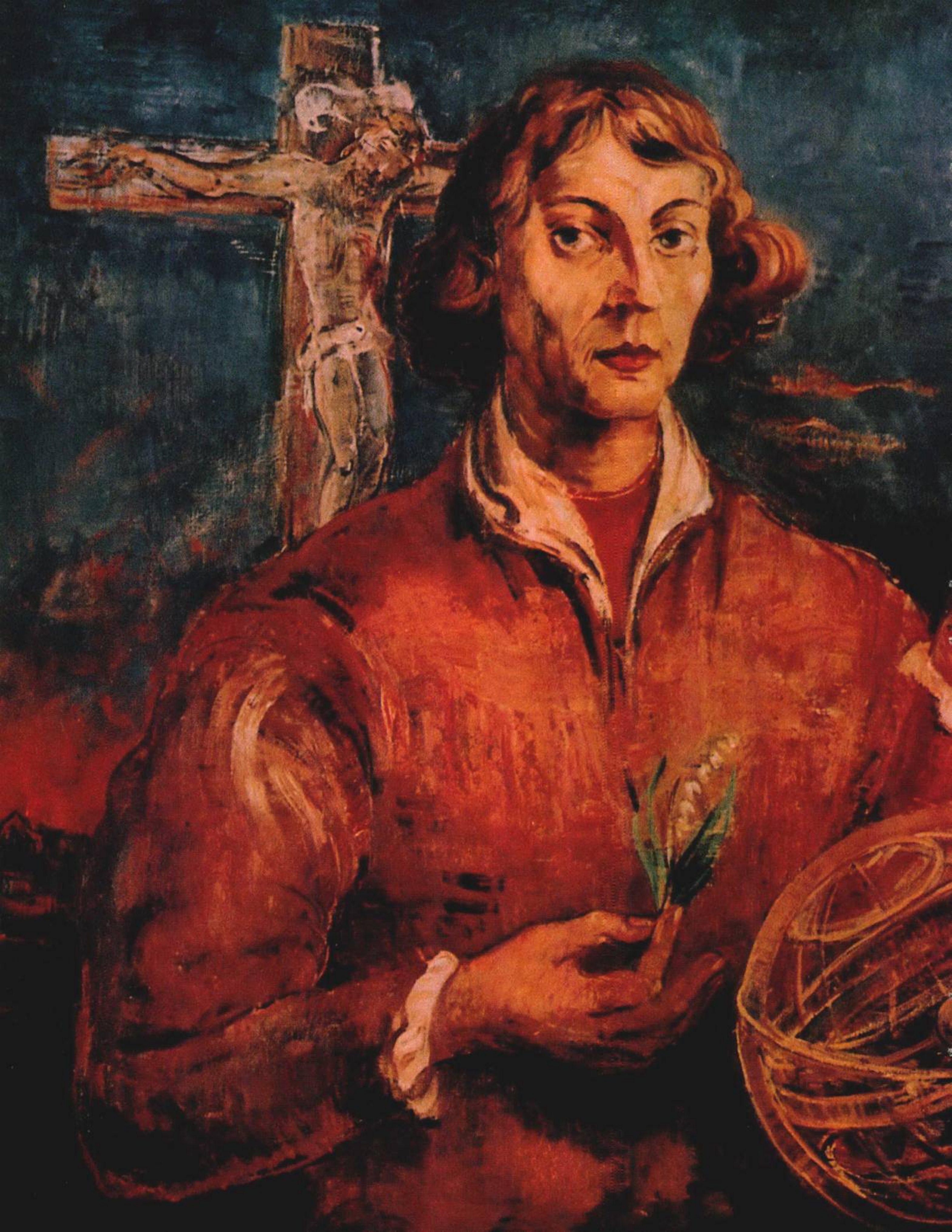
Oddly enough, now that particle theorists have started thinking about this new funny stuff, their calculations are producing too much of it rather than too little. Of course, theorists are like that.

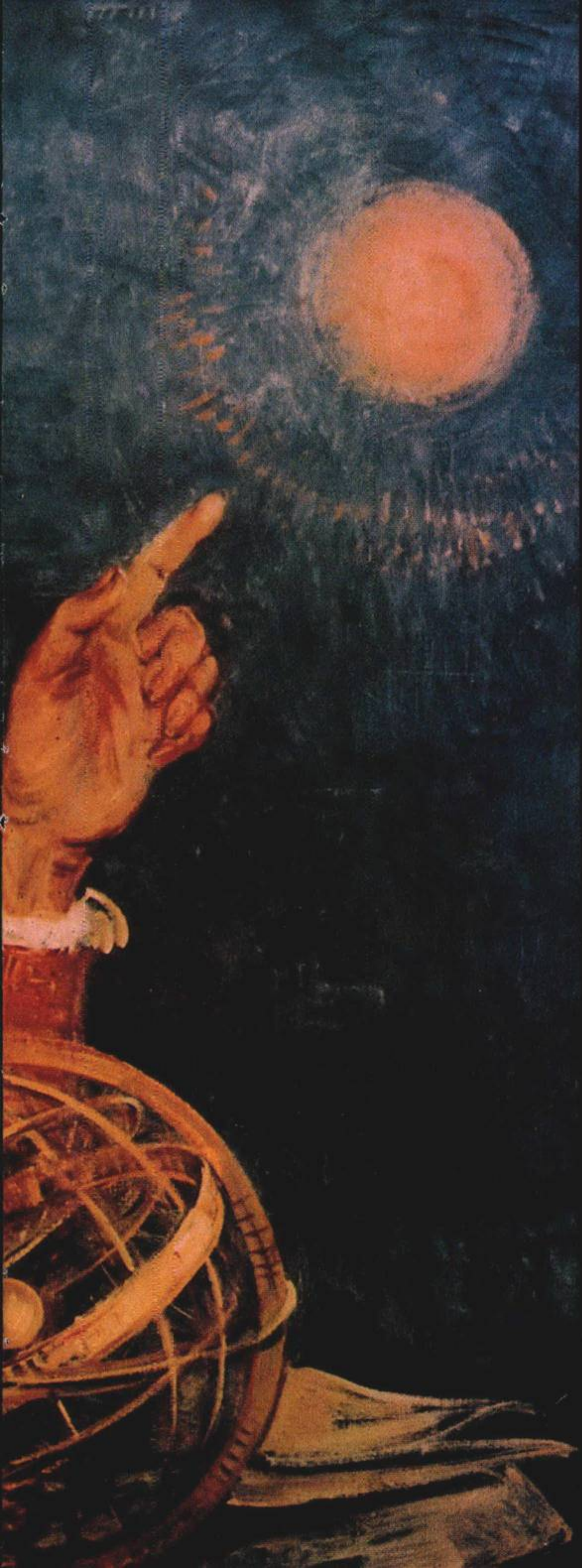
Once it's all been settled, I'm going to crack open a beer, kick back, and count myself lucky to have reported some of the century's most thrilling scientific action. ■

James Glanz covers physics and astronomy for Science.

Supernova 1994D, lower left, which exploded on the outskirts of galaxy NGC 4526, is one of more than 120 type Ia supernovae discovered in the past few years.

High-z Supernova Search Team, HST, NASA





An Unlikely Revolutionary

Nicolas Copernicus, circumscribed by orthodoxy and steeped in Catholicism, triggered a scientific transformation.

by Rosemary Sullivant

NICOLAS COPERNICUS WAS BORN IN A DIFFERENT universe. Earth sat fixed in the center of it, while the sun and the planets revolved it in a series of crystalline spheres. Aristotle had described this universe nearly 2,000 years before. However, Copernicus set Earth in motion, removed it from its place of honor, and put the sun there instead.

The ancient Greek astronomer and mathematician Aristarchus of Samos was the first to propose such a heliocentric universe, though few knew of his work. Later, the Pythagoreans took a similar view. But Copernicus changed astronomy forever with his heliocentric idea and started a revolution in science, philosophy, and religion.

"The Copernican Revolution was, in the final analysis, not just the change from a geocentric to a heliocentric world view. Rather, its power lay in a whole new way of looking at nature and at the role of observation," says Owen Gingerich, professor of astronomy and history of science at Harvard-Smithsonian Center for Astrophysics. "Curiously enough, in this regard Copernicus scarcely belongs in the modern world. Although Copernicus is not

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celebrated for his observations, it was in the Copernican tradition that Kepler and Galileo taught us to use logic and fresh observations to distinguish between various hypothetical world views, leaving only those consistent with the observations."

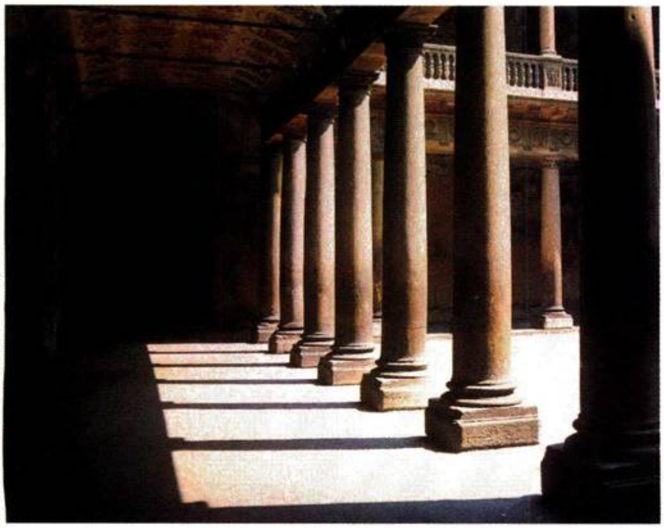
Not all revolutionaries are colorful. Copernicus certainly wasn't. He lived a circumscribed life as a physician and civil servant within the Catholic Church. Little is known about him. A biography was lost, and most of his papers have disappeared. Only copies of his self-portraits remain.

"There is no way to know what he was like," says Gingerich. "One hasn't a clue if he was shy or reticent, if he was arrogant, if he was sensual. None of those kind of things do we really know." About astronomy, he wrote; "Insomuch as the aim of all noble sciences is to draw man away from evil and to guide his mind towards greater perfection, then this of all the sciences can, in addition to unimaginable mental bliss, effect this in fuller measure than the others."

Politically Connected

Copernicus was born February 19, 1473, in the Polish city of Torun, then part of Prussia. His father was a successful merchant and his mother, Barbara, was from a prosperous, well-

Previous page: This 1944 painting by Maxim Kopf of New York was intended to show how Copernicus probably looked.
Left: Copernicus's birthplace in Torun, Poland.
Bottom left: Copernicus studied medicine in this building in Padua, Italy.
Bottom: The rear tower at Frombork cathedral where Copernicus wrote *De Revolutionibus*.



Previous page: Photo of painting by Maxim Kopf courtesy of Owen Gingerich

Left and bottom left photos by Owen Gingerich

Photo by Charles Eames, courtesy of Owen Gingerich

connected family. Nicolas was the youngest of two boys and two girls.

When he was 10, his father died, and Lucas Watzenrode, his uncle, became his and his siblings' guardian. Watzenrode, Barbara's older brother, was an ambitious, powerful man who made his career in the church. He studied at the universities of Kraków, Cologne, and Bologna. By the time Copernicus was 16, his uncle was bishop of Warmia, a state in northernmost Poland. Legend says Watzenrode never smiled in public, and he probably was not a warm paternal substitute. However, he took his guardianship seriously, as he apparently did everything.

Copernicus probably received his early schooling at parish and cathedral schools in Torun. Copernicus was 18 in the fall of 1491 when his uncle sent him and his brother, Andreas, to study at the University of Kraków. This was probably where he was first introduced to astronomy and learned to use astronomical instruments. Copernicus studied there for four years, trying painting among other subjects. Mikolaj Kopernik also perfected his Latin and adopted the Latinized version of his name by which we know him.

In 1495, Bishop Watzenrode called Copernicus to Warmia. He had nominated his nephew as a canon in the cathedral at Frombork. Canons were salaried, church administrators. However, somebody else got the job, so Watzenrode sent Copernicus and Andreas to Italy for further study.

In October 1496, Copernicus enrolled to study church law at the University of Bologna, where his uncle had received his doctorate in the same subject. About the same time, Watzenrode had Copernicus named a canon of Frombork, a post that guaranteed him an income. Watzenrode later did the same for Andreas.

Copernicus spent almost four years in Bologna. While law and Greek were his official courses of study, astronomy was probably of more interest. His first recorded observations were made with the university's famous astronomy professor Domenico Maria Novara. Copernicus was more than a mere student of astronomy. He later described himself as an assistant and witness of the observations rather than a pupil.

Copernicus made a pilgrimage to Rome during the jubilee year of 1500. A year later, he and Andreas went back to Warmia to ask the Frombork chapter for permission to return to Italy for more study. The chapter agreed but with the stipulation that Copernicus study medicine. Andreas went to Rome and Copernicus enrolled in the medical school at Padua. There, along with medicine, he continued his study of Greek to better understand the knowledge of the ancient world.

When it came time for him to return home in 1503, Copernicus, 30, took a degree at the University of Ferrara in canon law, not medicine.

> "There is no way to know what he was like," says Gingerich. "One hasn't a clue if he was shy or reticent, if he was arrogant, if he was sensual. None of those kind of things do we really know."

Revealing Self-Portraits

As usual, Watzenrode called the shots in his nephew's life. Copernicus went to live at the bishop's palace in Lidzbark and became his uncle's secretary, physician, and companion. Watzenrode was busy. Warmia was in the midst of ongoing conflicts with the militant Germanic Order of the Teutonic Knights and Poland. Copernicus's life was filled with politics, church business, and travel with his uncle. During this time, Copernicus became interested in cartography and drew what is said to be the first map of Warmia and the western borders of Royal Prussia.

Perhaps inspired by the Renaissance, Copernicus may have used some of his time at Lidzbark to paint his self-portraits, writes Edward Rosen in *Three Copernican Treatises*. "With the practice of medicine uppermost in his mind, and his astronomical system not yet fully developed," he writes, "Copernicus chose to portray himself holding in his hand a lily of the valley as a symbol of the healing art." In another painting, Copernicus paints himself as a scholar with a book. Both portraits are secular. The surviving authentic copies "stand in stark contrast to the later spurious products emphasizing Copernicus's supposed religiosity," says Rosen.

Copernicus continued to study Greek and in 1509 published a Latin translation of Greek letters by a seventh-century Byzantine historian. Copernicus dedicated the collection of moral, pastoral, and love letters to his uncle: "To you, Right Reverend Bishop, do I dedicate this modest gift which, however, can by no means be compared to your generosity." To avoid any questions about the propriety of the love letters, Copernicus explained; "Just as physicians usually moderate the bitterness of drugs by sweetening them to make them more palatable, so these love letters have in like matter been rectified, with the result that they ought to receive the label 'moral' no less."

This book, writes astronomer Fred Hoyle in *Nicolaus Copernicus: An Essay on His Life and Work*, provides a rare glimpse of the man in flesh and blood. "Except in this one moment," he says, "I cannot hear Copernicus laugh."

Copernicus was drawn to Earth's motion. Before 1514, he described his theories in *Commentariolus*, in which he states for the first time that Earth is a planet in motion. The first of seven assumptions, "There is no one center of all the celestial orbs or spheres," directly contradicts the prevailing geocentric view of the cosmos. The sixth states, "What appear to us as motions of the sun are due, not to its motion, but to the motion of Earth and our sphere, with which we revolve about the sun." The passage refutes the fixed Earth of the Aristotelian universe.

Why did he choose to adopt a heliocentric system? "It was for him something very beautiful," says Gingerich. " 'A theory pleasing to the mind,' but a vision in mind's eye that he could not demonstrate by any observational tests. As Galileo later said, he could not admire enough those who adopted the heliocentric view despite the evidence of their senses."

Copernicus never intended to publish the untitled, unsigned manuscript, but he sent copies to astronomer friends. He promised that a more thorough explanation would follow. It was a promise he almost didn't keep.

Palace Life

In 1510, Copernicus left his uncle's palace — possibly because of a break between them — to live in Frombork. Watzenrode wanted his nephew to advance, perhaps succeeding him as bishop, but Copernicus may have had other ideas. He fondly described Frombork as the "remotest corner of Earth." Except for two brief periods away on church business, he would spend the rest of his life there.

In spring of 1512, the 65-year-old Watzenrode suddenly became ill and died. The same year, Copernicus's brother, Andreas, was relieved of his duties at Frombork and left for Rome, never to return. Andreas was ill, possibly due to leprosy contracted during his student years. He died in 1518.

Copernicus lived in a house outside Frombork's cathedral walls. He may have had his observatory on one of the towers. A church official, Copernicus never became a priest, even though Galileo would later say he did. Indeed, most of the 16 canons then at Frombork were administrators.

Copernicus was a chancellor and inspector of the chapter estates and took part in councils and meetings. As Newton was to do more than 150 years later, Copernicus concerned himself with coinage and monetary policy. He is credited with being one of the first to state the law that good coins are driven out of circulation by baser ones. He also worked on calendar reform, an important subject closely linked to his astronomical interests.

Copernicus, the Doctor

Copernicus built a reputation as a caring physician. "We are being visited today by Doctor Nicolaus Copernicus who, applying the art of medicine, is tending to our illnesses with assiduous care," wrote Bishop Maurycy Ferber in 1532 and quoted by Jan Adamczewski in his book, *Nicolaus Copernicus and His Epoch*. Notes of "caution" are repeatedly written in his medical books.

> "He has but few persons who care about him and who would be concerned about his state of health, though we are all indebted to him for his unimpeachable character and conspicuous learning."

From 1516 to 1519 and from 1520 to 1521, Copernicus oversaw the chapter's estates while living away from Frombork. He lived in the castle in Olsztyn, where he constructed an experimental table based on the principle of a reflective sundial to observe the movements of the sun and Earth. Part of his job was to establish new settlers on lands abandoned during the continuing wars with the Teutonic Knights. "Brosien Trokelle took possession of three parcels, made vacant by the death of Peter," Copernicus recorded in 1517. "In addition to these parcels, Brosien got two horses, one cow, three she-goats, two piglets, one sack of rye, and three sacks of oats. He will pay rent for the first time next year."

When Olsztyn was threatened by the Teutonic Knights in 1520, Copernicus led the chapter's resistance, earning himself a place in Poland's history as a courageous military leader and patriot. After a truce was signed with the Teutonic Knights in the1520s, Copernicus became Commissioner of Warmia with even more responsibility. His work as an administrator and physician would continue throughout his life, just as would his study of the stars.

Copernicus probably started writing *De Revolutionibus* around 1515. He would have begun about the time, says Gingerich, that he got a copy of *The Almagest*, Ptolemy's monumental attempt to describe the geocentric universe mathematically. "Copernicus can see at that point just how major a thesis is required to complete what he had begun in *Commentariolus*. Now he realizes that he has to follow the planets around their orbits so that he can get the contemporary observations to confirm Ptolemy's parameters."

Making those observations would take about 15 years, if he were lucky, says Gingerich. "He is willing to go into the administrative work for the chapter because he is essentially biding his time until Copernicus can get the observations he needs."

The first part of *De Revolutionibus* presents a general description of the heliocentric universe and includes Copernicus's reasons for such a world. The second, much longer, part is his answer to Ptolemy. It is a technical analysis of the movement of the sun, the moon, and the planets, with tables for predicting planetary positions. It was written, as Copernicus said, "for mathematicians."

Copernicus started with an aesthetic ideal — planets moving in perfect circles around the lantern of the sun in uniform motion. If he was right, he reasoned, he should be able to calculate the motions of the spheres better than mathematicians of the past. Not only have they had to come up with all sorts of strange and inconsistent ways to describe the motions of the sun, moon, and stars, he writes in his introduction to the book, "Also, they have not been able to discover or deduce from them the chief thing, that is the form of the universe, and the clear symmetry of its parts. They are just like someone including in a picture hands, feet, head, and other limbs from different places, well painted indeed, but not modeled from the same body, and not in the least matching each other, so that a monster would be produced from them rather than a man."

Copernicus found the elegant, harmonious world he imagined. He writes, "... I eventually found, by long and intensive study, that if the motions of the wandering stars are referred to the circular motion of Earth and calculated according to the revolution of each star, not only do the phenomena agree with the result, but also it links together the arrangement of all the stars and spheres, and their sizes, and the very heaven, so that nothing can be moved in any part of it without upsetting the other parts and whole universe."

With his new sun-centered system, Copernicus explained why superior planets seem to move backward as the faster-moving Earth passes by them. Stars didn't behave the same way, he argued, because they were so far away.

Some of his ideas didn't work as well. He was convinced that planets move in uniform motion: In order to explain why planets move faster on one side of their orbits than another, he came up with the idea of epicycles — little, auxiliary circular orbits within the primary orbit.

Rise of Heliocentrism

But none of his observations proved heliocentrism. Most astronomers would see Copernicus's theories not as a description of physical reality, but as a way of calculating planetary positions.

As Copernicus continued work on *De Revolutionibus* throughout the 1530s, interest in his work grew. In 1533, Pope Clement VII was told about Copernicus's theory of the motion of Earth. Cardinal Nicholas Schonberg in Rome wrote to Copernicus in 1536 saying he admired his work, asking for a copy of his manuscript, and offering to pay all expenses. His friend, Bishop Tideman Giese, urged him to publish.

Criticism had begun as well. "Mention has been made of some new astrologer, who wanted to prove that Earth moves and goes around, and not the firmament or heavens, the sun and the moon," commented an angry Martin Luther in 1539. "This fool wants to turn the entire art of astronomy upside down! But as the Holy Scriptures show, Joshua ordered the sun, and not Earth, to halt!" Protestants proved initially more hostile to Copernicus. The Catholic resistance grew later.

De Revolutionibus would probably never have been published at all without the appearance at Copernicus's door in May 1539 of George Joachim von Lauchen. He was a brilliant, 25-year-old Lutheran astronomy professor from Wittenberg University. He went by Rheticus, taken from the Latin name of his home region. Rheticus had heard about Copernicus's work and then found him in Frombork. The young astronomer apparently came for what was planned to be a short visit but stayed for nearly two years and became Copernicus's only disciple.

Copernicus welcomed Rheticus and let him read his manuscript. Rheticus was very enthusiastic. His *Narratio Prima* outlining Copernican astronomy was published in 1540.

"If anyone desires," he wrote, "to look either to the order and harmony of the system of the spheres, or to a complete explanation of the causes of the phenomena, by no other hypotheses will he demonstrate more neatly the apparent motions of the planets. For all these phenomena appear to be linked most nobly, as by a golden chain; and each of the planets, by its position and order and very inequality of its motion, bears witness that Earth moves."

In 1541, Copernicus agreed to have his work published, although he was still revising. Rheticus returned to Wittenberg and in 1542 published a section on trigonometry. Later, Copernicus turned over his complete manuscript for *De Revolutionibus* to his friend Giese, who forwarded it to Rheticus.

During this period, Copernicus's bishop forced him to give up his housekeeper Anna Schilling, a distant relation. She was a cultured, attractive woman of whom he apparently thought very highly. The bishop, himself no moral paragon, judged the woman suspect. Copernicus, who never married, resisted the bishop's demands for months before dismissing Anna.

A Papal Appeal

In June 1542, Copernicus sent his preface to Rheticus, dedicating the book to Pope Paul III. "I can easily conceive, most Holy Father, that as soon as some people learn that in this book which I have written concerning the revolutions of the heavenly bodies, I ascribe certain motions to Earth, they will cry out at once that I and my theory should be rejected." He explained that he had agreed to publish only at the urging of others. His work, he said, had been motivated by "the uncertainty of the traditional mathematical methods of calculating the motions of the celestial bodies," and appealed to the pope to "suppress the bites of slanderers."

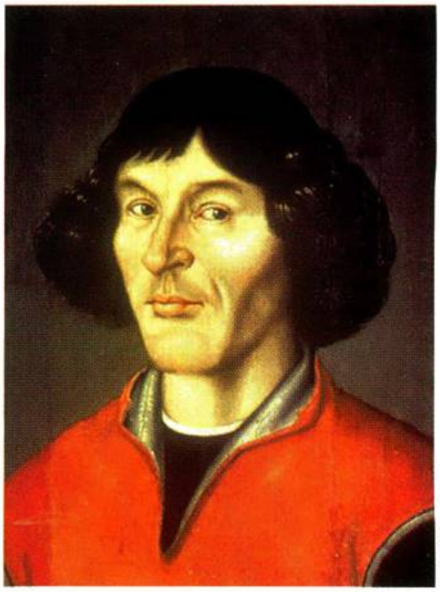
While the book was in press, Rheticus was called away. He left the proofreading to Andreas Osiander, a Protestant theologian. Osiander knew of Copernicus's work and had earlier corresponded with him. Perhaps in an attempt to make Copernicus's ideas more acceptable, Osiander inserted his unsigned introduction. In this, Osiander, in contradiction to Copernicus's intent, asserted that the contents of the book were not meant to be true but only a working hypothesis to explain certain phenomena. He may also have altered the title page, the original of which is lost, changing the name of the work from *De Revolutionibus* to *De Revolutionibus Orbium Coelestium* (On the Revolution of Heavenly Spheres).

By now, Copernicus was sick and alone. Giese wrote to one of Copernicus's fellow canons: "He has but few persons who care about him and who would be concerned about his state of health, though we are all indebted to him for his unimpeachable character and conspicuous learning."

Copernicus died May 14, 1543, the day the finished book was put in his hands. He was buried in Frombork; nobody knows precisely where. He was 70. His revolution had scarcely begun.

For many, the publication of *De Revolutionibus* signaled the birth of modern science. Observation and reason replaced tradition or dogma as ways to understand nature. Earth revolves around the sun like the other planets. The universe is vast and beautiful, and the possibilities are infinite. ■

Rosemary Sullivant is a freelance science writer in Los Angeles, California.



Octavo Corporation

This 16th-century painting in the Torun, Poland, town hall by an anonymous artist was based upon a Copernicus self-portrait sketch.

Surviving in

Before humans can explore Mars, scientists must know if our bodies can withstand the extreme conditions of space.

by Diana Steele

When Mars Pathfinder landed in July 1997, it captured the world's attention and sent back stunning images and chemical analyses of the rocky surface. We watched in awe, wondering about touching red martian soil. Likewise, scientists want to send a team to explore Mars, the most likely planet in our solar system (other than Earth) to have life.

A trip to Mars is expected to take about 500 days — 200 traveling and 300 exploring. To survive, a crew would need to carry life-sustaining supplies, or yet-to-be-developed technology to recycle martian air, water, metals, and other materials. But all this is expensive. And even if scientists overcome the technological hurdles, the physical demands of a long spaceflight are still considered too risky.

Long-term weightlessness and exposure to radiation wreak havoc on the human body. Without gravity, bones and muscles deteriorate in ways similar to those experienced by people with osteoporosis or paralysis. It also causes at least temporary changes in the neurovestibular system, which controls balance. Radiation exposure causes cancer.

Despite the risks, astronaut Shannon Lucid is ready. She holds the United States record for the longest mission in space — six months. "If somebody walks into the office today and says, 'We've got the secret vehicle, are you ready to go tomorrow?' I'd say, 'Sure, let's go!' "

Although *she's prepared*, scientists aren't. Even though astronauts have been exploring space for 50 years, we still have much to learn about how the human body would fare during a trip to Mars. Fortunately, researchers have learned much. Space shuttle trips double as experiments, and scientists are learning from them how the body responds. Experiments conducted on board these flights test bone loss, muscle atrophy, balance, and radiation exposure to help determine some of the physiological risks and how to lessen them.

Losing Tissue

Bone and muscle loss represent a critical area of space-travel research. On Earth, muscles and bones develop strength by constantly working against gravity. In the near-weightlessness of space, they deteriorate. NASA astronaut David Wolf lost 40 percent of the strength in his back muscles alone during his 4½-month stay on Russia's Mir Space Station. "You don't realize how much exercise a human gets just living in a gravity field," he says. "Rolling over in bed is a lot of exercise compared to what you get in space."

Bones, no longer stressed by gravity, deteriorate rapidly — one to three percent a month. The vertebrae, pelvis, and leg bones — key weight-bearing bones — suffer the most.

No one knows when, or if, the loss stops. In injury-caused paraplegia, bone loss continues for nearly two years before stoping. No one has yet been in space long enough to know if the two-year decline is the same for astronauts. Another question is how quickly or fully astronauts would regenerate lost bone cells when they return to Earth. Most bone growth occurs

Space

during childhood, or after a bone has broken. However, researchers don't know how to stimulate bone growth in healthy adults. Most astronauts who have been in space for months have regained most of their bone mass upon returning to Earth, but they have done so slowly.

"The head of the femur is a part of me that will always be about four years older than I am," says astronaut Norm Thagard, who spent five months on Mir. "I'm 55, but that bone has the mineral level it would have at age 59."

Experiments conducted on the space shuttle and planned for the International Space Station include studies of the rate of bone and muscle loss and the effects of exercising or drugs on slowing or stopping that loss. Such studies are of keen interest to Scott Smith, a nutritionist at the Johnson Space Center. He studies calcium metabolism — how the body uses, stores, and loses calcium before, during, and after space flights. So far, he and his colleagues have studied two astronauts and four cosmonauts on board the Mir. They plan to repeat their studies on astronauts who tend the International Space Station once it's operating.

Smith's experiments involve injections before, during, and after flight. Each astronaut gets a small dose of a radioactive isotope of calcium that is used as a "tracer." At regular intervals, Smith collects saliva, urine, and blood from the astronauts and determines where the tracer calcium migrated. He finds out how fast calcium becomes bone, and how quickly existing bone breaks down. As expected, Smith's preliminary data show that space travel accelerates bone breakdown and reduces bone formation.

According to Smith, the body loses about ¼ gram of bone calcium each day in space. Once the astronauts have returned to Earth, calcium rebuilds much more slowly than it was lost, regaining only about ⅒ gram per day. "It's going to take two to three times the length of the mission to recover the lost bone," he says. So far, only one of the people he has studied has fully recovered their bone mass.

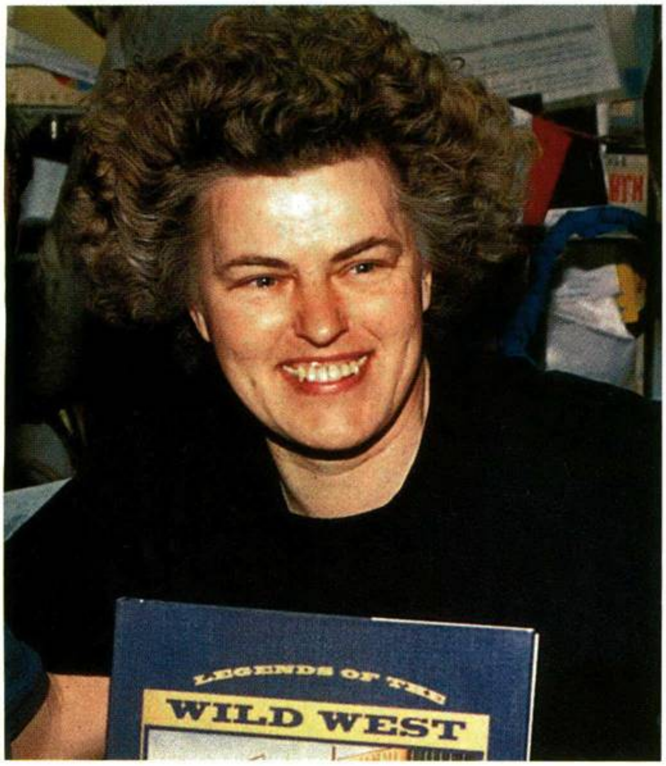
One way to compensate for the bone loss has been to take calcium or vitamin D supplements, but it hasn't worked well. The calcium not used by the body accumulates in the kidneys where it can form painful kidney stones. One cosmonaut had to abort a mission in November 1985, possibly due to a kidney stone. Smith says there is some hope that drugs used to treat osteoporosis may help. His colleague Linda Shackleford is testing the effects of the drugs on the ground. If results prove promising, she will test them in flight.

Some scientists believe daily exercise will prevent bone loss. Russians cosmonauts, for example, have implemented a daily two-hour exercise program in an effort to preserve bone and muscle mass. "We don't know if it helps, because we don't have the data, and neither do they," says John Charles, coordinator of life sciences research for a Mars mission at NASA's Johnson Space Center.

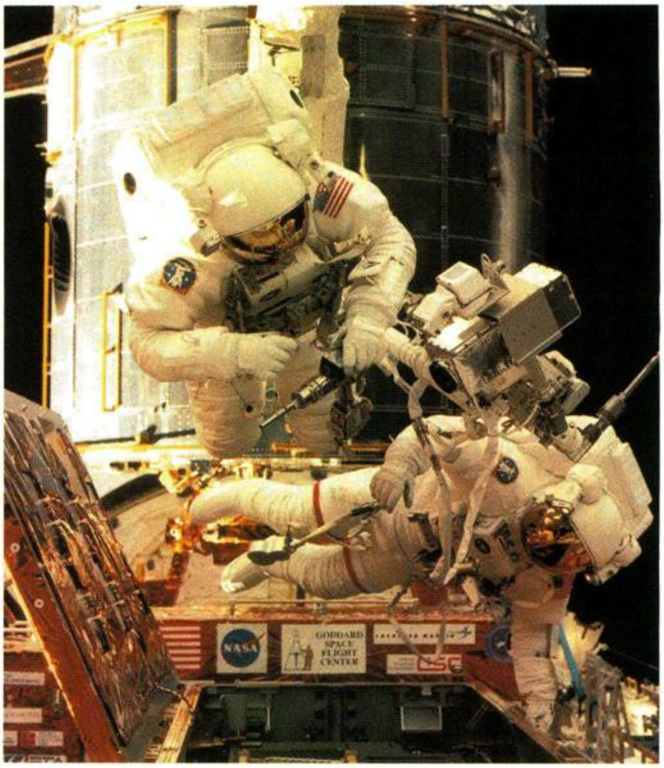
Indeed, astronaut Wolf reversed some of his early muscle losses on Mir by exercising while attached with a harness to a bicycle and a treadmill. "The distribution of the load is different with a harness than would be applied through gravity, which distributes the load," he says. "So it's difficult, if not impossible, to recreate the true effect of gravity with it."

The International Space Station will carry more sophisticated aerobic and strength-exercise equipment, although scientists suspect it won't prevent bone and muscle loss.

Previous page: Astronauts Carl Meade, left, and Mark Lee practice a rescue maneuver while anchored to Discovery in 1994.
Bottom left: Astronaut Shannon Lucid smiles while off duty during her five-month tour aboard Russia's Mir Space Station in 1996.
Bottom right: Mission specialist Steven Smith, left, and payload commander Mark Lee were part of a four-astronaut team that serviced the Hubble Space Telescope, background, during a 1997 shuttle mission.
Opposite page: Hamming for the camera on a Discovery mission are, left to right, Kent Rominger, Robert Curbeam, Stephen Robinson, Curtis Brown Jr., N. Jan Davis, and Bjarni Tryggvason.



All photos: NASA



"It would do us no good to get to Mars and not be able to explore it," says Wolf. "Which leads to another unanswered question: is the ⅓ gravity of Mars more like zero G or more like one G?" Since rats show many of the same effects of weightlessness as humans, the rodents will be housed in cages within spinning centrifuges aboard the International Space Station in an attempt to simulate the gravitational environment of Mars.

A Delicate Balancing Act

Not only does weightlessness create problems in human bones, it disturbs balance. Going from Earth's gravity to a weightless environment, or vice versa, at least temporarily disrupts a person's ability to maintain balance and may be critical in the event of an emergency landing on Earth or Mars. Astronauts suffer from a balance disorder after extended spaceflight, but researchers have too little data to know how long it persists.

Suddenly becoming weightless can feel like standing on the deck of a small boat in a heaving surf. So-called proprioceptor systems in our eyes, inner ears, and joints receive mixed signals and work together to maintain balance: Our joints no longer feel the pressure of gravity, but we see the sky above the deck. It's confusing and can cause nausea.

In microgravity, the inner ear adds to the confusion by sending conflicting information to the brain. Tiny fluid-filled canals in the inner ear respond to changes in linear acceleration — like starting up or down in an elevator. Calcium carbonate crystals, called otoliths, press on tiny hairs when the head accelerates up, down, or sideways, sending signals to the brain. In space, the otoliths float freely within the ear, making astronauts feel dizzy and nauseated for the first few days of each spaceflight.

Eventually the brain somehow figures out how to deal with all the conflicting information. When that happens, the stomach distress subsides. Evidence from experiments with rats on the space shuttle suggests that a physical rewiring of neurons takes place in their brains.

"We find that when people go into space, the loss of gravity — a stimulus to some of the sensors — causes the brain to changes the way it processes that information," says Bill Paloski, chief of NASA's Life Sciences Research program and a neuroscientist at the Johnson Space Center. "This means that they are adapted for zero gravity and maladapted for Earth's environment." Once back on Earth, astronauts usually find it difficult to stand or walk for at least a few days without feeling dizzy.

"On all my previous flights, I couldn't tell I'd been in space the day after I'd landed," says Thagard. "But after Mir it was about five days. We landed on a Friday and it was Wednesday of the next week before it didn't feel at least a little funny from a balance standpoint."

Thagard was lucky. Immediately after landing, most other astronauts react as if they've just stepped out on an ice rink, and their bodies stiffen in response to any threat to their balance. Even though the nausea and dizziness abate relatively quickly after the return to Earth, evidence from other experiments indicates that other, more subtle changes in balance control persist for months, perhaps longer. Astronauts say they have trouble maintaining their balance if they move their heads quickly or walk into a dark room. Even walking on a thick carpet can disorient them. "A similar thing happens in aging individuals, where changes occur in the sensors themselves, particularly in their inner ears," says Paloski. Normally, overlapping data from the eyes, inner ear, and proprioceptors work together with the ankles, hips, and muscles. But after space flight, those systems don't work efficiently.

Paloski measures how well astronauts can control their balance after returning to Earth by seeing how they respond to a shifting floor beneath them. It is a challenge. They stand on a platform that can tilt or move suddenly back and forth. For a subtle threat to balance, the initial response is to use the ankles to absorb the shock. If the perturbations are more stability threatening, the hips come into play. And if the movement of the platform is beyond the astronauts' perceived ability to maintain their balance, they take a staggering step. Paloski looks for transitions between coping strategies, how small a movement does it take before someone takes a step rather than using their hips or ankles to maintain their balance.

"Our main concern is that there is a safety issue in an emergency landing," Paloski says, "and this becomes a real concern on any future interplanetary exploration, a trip to Mars for example."

The most appropriate countermeasures will probably involve some sort of artificial gravity system, such as a centrifuge or rotating vehicle. He says astronauts could learn to adapt both to weightlessness and gravity at the same time. "We know that people can multiply adapt," he says, "it's like putting on or taking off spectacles."

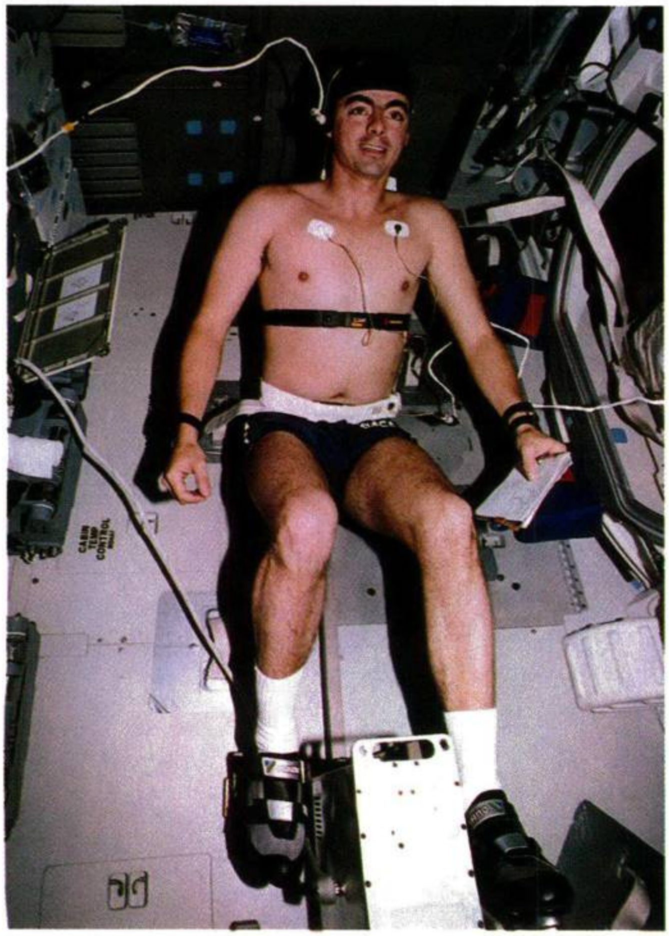
Chances exist of permanent changes in astronauts' abilities to keep their balance or direct their gaze. One ability that could be at risk to permanent damage is the vestibular-ocular reflex, which is the ability to keep the eyes on the same target even as the head is turned.

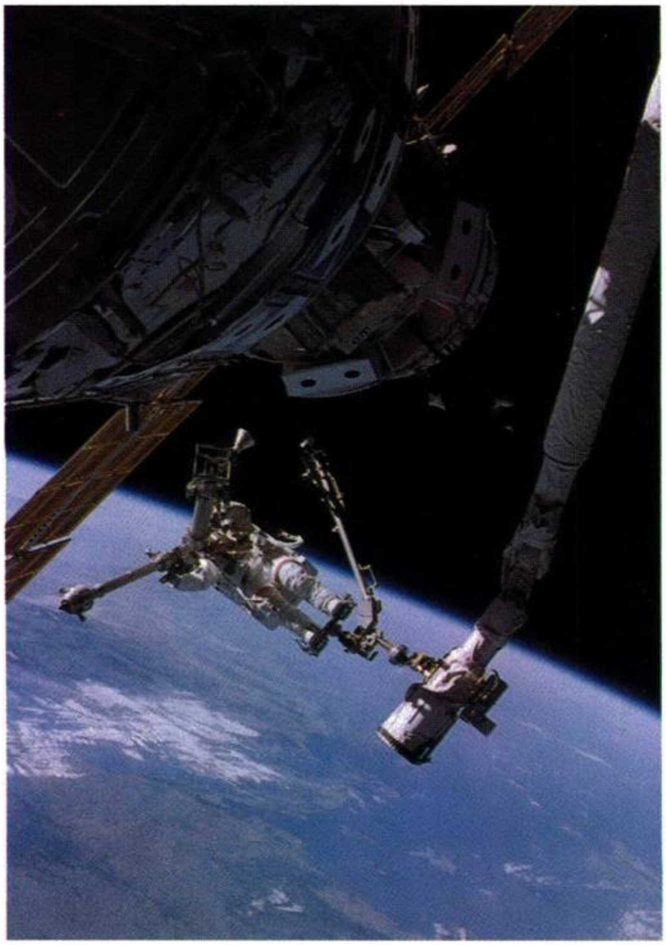
A landscape painter suffering from this ailment, for example, might find that it takes so long to focus on the easel that he or she forgets what was in the landscape. To complicate matters, Paloski says such neurological damage to astronauts is impossible to attribute to their prior space travel. He said the normal aging process can cause similar effects. And there

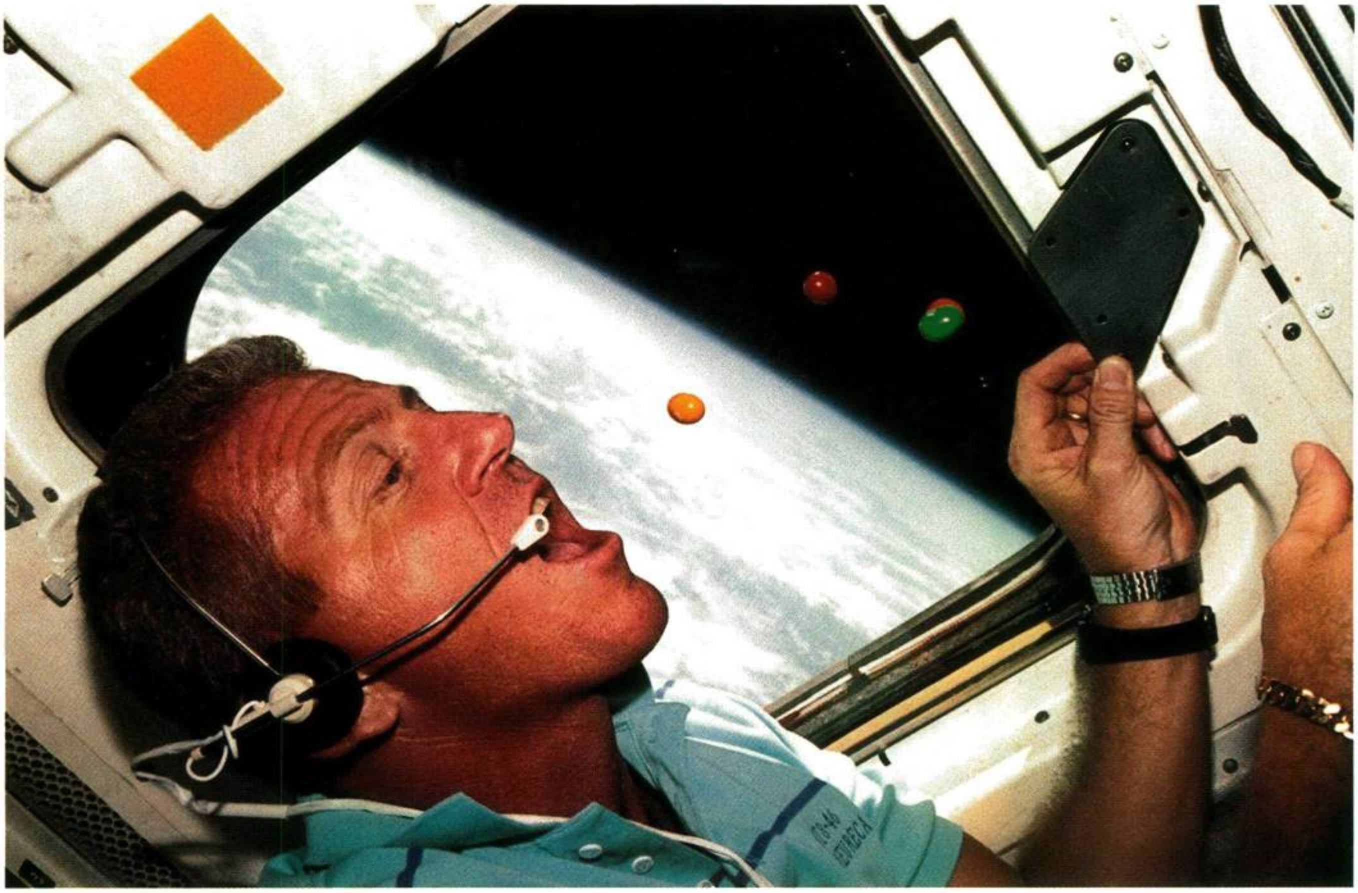
Bottom left: Attached to sensors, astronaut Andrew Allen exercises on a bicycle ergometer during his eight-day mission on Atlantis. The eight-day mission in 1992 involved 127 Earth orbits and included four other NASA astronauts and two European scientists.

Bottom: The Aegean Sea acts as a backdrop for astronaut Tamara Jernigan as she moves the American-built crane that she helped install on the International Space Station. During her May 30, 1999, space walk her feet were anchored to Discovery.

Opposite page: Astronaut Loren Shriver pursues several floating chocolate candies on the flight deck of Atlantis.







is no way to know what — aging or extended spaceflight — caused such problems.

Dangerous Rays

Beyond the immediate physiological effects of long-duration spaceflight, scientists worry about the potential harm from space radiation. Dangerous radiation includes x rays, gamma rays, cosmic rays, and high-speed solar particles.

The effects of x rays and gamma rays were documented in extensive studies of radiation-therapy patients and nuclear bomb victims. But the biological effects of cosmic rays and solar particles are much less well-characterized because Earth's atmosphere largely shields people from them.

Experiments at particle accelerators here on Earth and with animals and tissue culture in space may eventually provide some answers about how much of these types of radiation can be tolerated before inevitable damage leads to the development of cancers or outright cell death that triggers neurological side effects.

"Radiation-induced cancers typically have a long latency — 10 or 15 years," says Michael Golightly, a space radiation expert at NASA's Johnson Space Center. "So it's not something that we would expect astronauts to have to deal with during the mission, but it's something they could face after they get back."

To further complicate matters, animal studies suggest that moderately high doses of these particles can also damage brain tissue. Neurons die along the particle's path. It is assumed that humans would be similarly affected.

Galactic cosmic rays are composed of ions ranging from low-atomic-weight hydrogen up to heavy atoms such as uranium. These high-energy particles come from outside the solar system in a more or less steady stream, modulated by the solar cycle. Ironically, the influx of ions is greater when solar activity is low, and vice versa.

"As funny as it sounds, it's probably best to fly a Mars mission at solar maximum," says Golightly. "The galactic cosmic ray flux is cut by something like a factor of two or three. The problem is, at solar maximum, you run a greater risk of experiencing one of these solar particle events, where a coronal mass ejection is accelerating particles. But since those particles don't seem to be as energetic as galactic cosmic rays we think we can build the spacecraft in such a way to shield the astronauts from those effects."

When a cosmic ray hits another atom, for example the aluminum of a spacecraft skin, it doesn't bounce off. Instead, it causes the aluminum atom to fragment into a cascade of daughter particles, each potentially as dangerous as the initial ion, only much more numerous. So the best shielding material would be anything that has a lot of hydrogen — which can't fragment into smaller ions — such as water (made up of hydrogen and oxygen) or hydrogen fuel. One option for a Mars vehicle would be to provide a sleeping area surrounded by water tanks in which the crew could be shielded.

Because he's a physician in addition to being an astronaut, Wolf understands better than most people the physiological risks of extended spaceflight. Asked whether he'd go to Mars he says he'd have to think about it — but only overnight. ◼

Diana Steele works in Chicago as a freelance science writer specializing in astronomy, astrophysics, and physics. An intrepid traveler, Steele went to the South Pole in pursuit of a story. For her next journey, she hopes to travel to Mars.

THE SKY SHOW

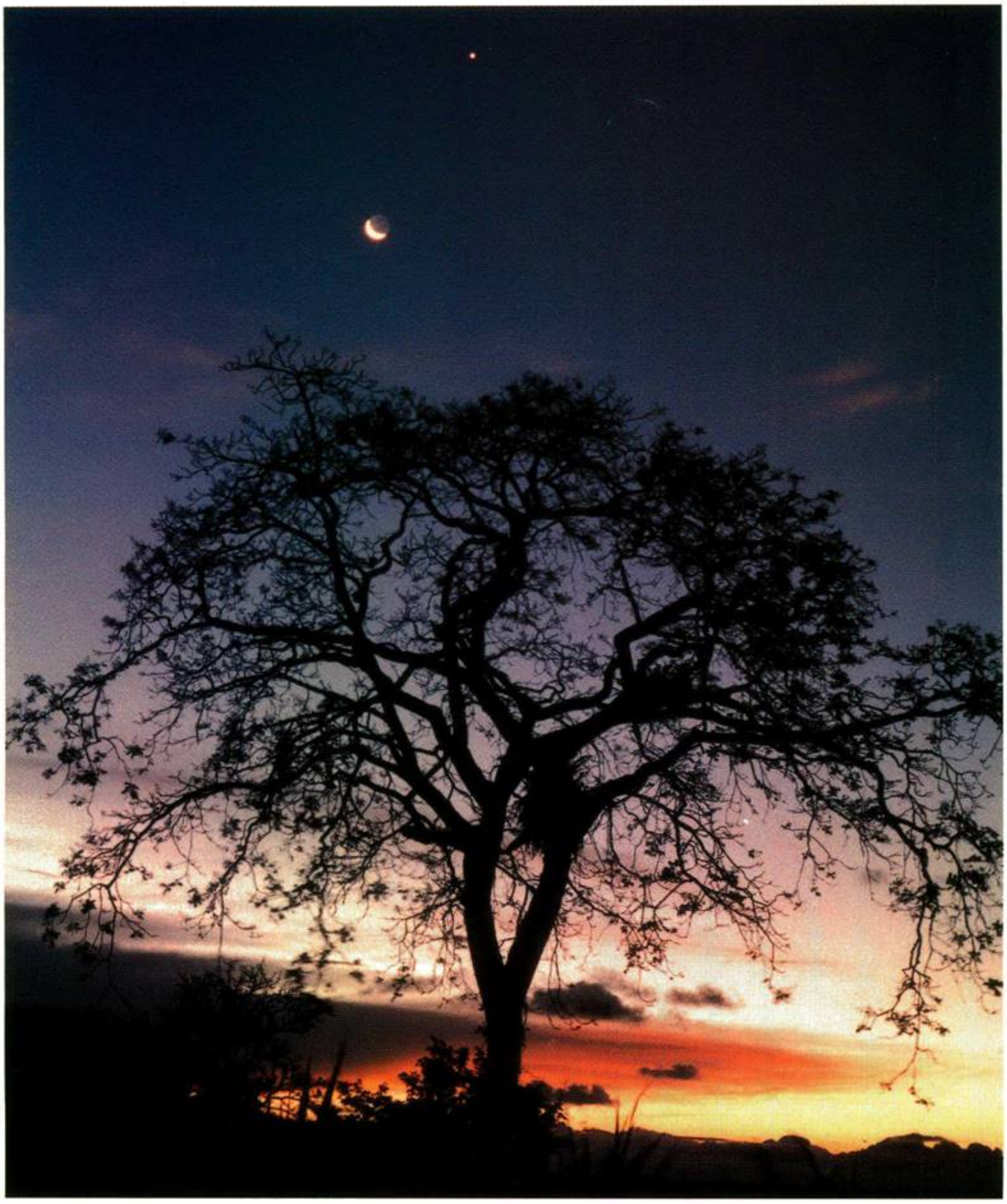
Jupiter and Saturn dominate the eastern sky after sunset, while Mars crosses the southern Milky Way and Venus shines at dawn. by Martin Ratcliffe and Alister Ling

▶If you take the dog for an early evening walk, cast your eyes low in the south for a bright reddish star. Actually, in early October, you'll see two of them side by side. The one on the right is truly a star, Antares, the rival of Mars. It is the most brilliant star in Scorpius the Scorpion. Slightly brighter and farther east lies **Mars**. The planet is receding from Earth and now lies more than 126 million miles away. Through a telescope, Mars presents a diminutive disk, but to the naked eye it still appears stunning. Shining brightly at magnitude 0.6, Mars is crossing the richest part of our Milky Way. Here, dense star clouds can be found as you peer toward the center of the galaxy.

Look for Mars at every opportunity, but take special care to get out the binoculars on the following dates. On October 4, the Red Planet skims past the 3.3-magnitude star Theta (θ) Ophiuchi. A telescopic view over just a couple of hours will show Mars's motion relative to the star. October 17 finds Mars only 0.8° south of the Lagoon Nebula (M8), while on the following night (October 18) Mars lies 0.3° south of the 8th-magnitude globular cluster NGC 6544. Mars rounds out the month by skimming past two globular clusters. It passes 0.5° south of M28 on October 23 and is 1° south of M22 on October 27.

The four largest planets in our solar system, Jupiter, Saturn, Uranus, and Neptune, are all on view this month. Jupiter and Saturn make up 92 percent of the total planetary mass of the solar system. They are truly giant planets. Uranus and Neptune are smaller, representing seven percent of the planetary mass. All the other planets combined, Mercury, Venus, Earth, Mars, and Pluto, account for the remaining one percent.

Neptune can be spotted in a small telescope with some patience. Look for it hanging roughly 1° west and slightly south of the 5.3-magnitude star Sigma (σ) Capricorni — Sigma rests south of the double star Alpha (α) Capricorni. The tiny bluish disk of Neptune shines at magnitude 7.9 and shows no detail. Even the Hubble Space Telescope has a hard time seeing details on this planet's disk. Back in 1989, the Voyager 2 spacecraft gave us the finest view to date of Neptune.



Jefferson Wang

The moon passes Venus on the morning of October 5, recalling this meeting from 1996.

OCTOBER 1999

2 Last quarter moon is at 12:02 A.M. EDT

5 The moon passes 5° north of Venus, 1 P.M. EDT
The moon passes 1.2° north of Regulus, 6 P.M. EDT

8 Venus passes 3° south of Regulus, 6 P.M. EDT

9 New moon is at 7:34 A.M. EDT

10 The moon passes 7° north of Mercury, 11 P.M. EDT

14 The moon is at apogee (251,814 miles from Earth), 9:50 A.M. EDT

15 The moon passes 5° north of Mars, 9 A.M. EDT

17 First quarter moon is at 11:00 A.M. EDT

18 The moon passes 0.5° north of Neptune, 3 A.M. EDT

19 The moon passes 0.4° north of Uranus, 1 A.M. EDT

22 Orionid meteor shower peaks

23 Jupiter is at opposition, 3 P.M. EDT (page 70)

24 The moon passes 4° south of Jupiter, 1 P.M. EDT
Full moon is at 5:02 P.M. EDT
Mercury is at greatest eastern elongation (24°), 6 P.M. EDT

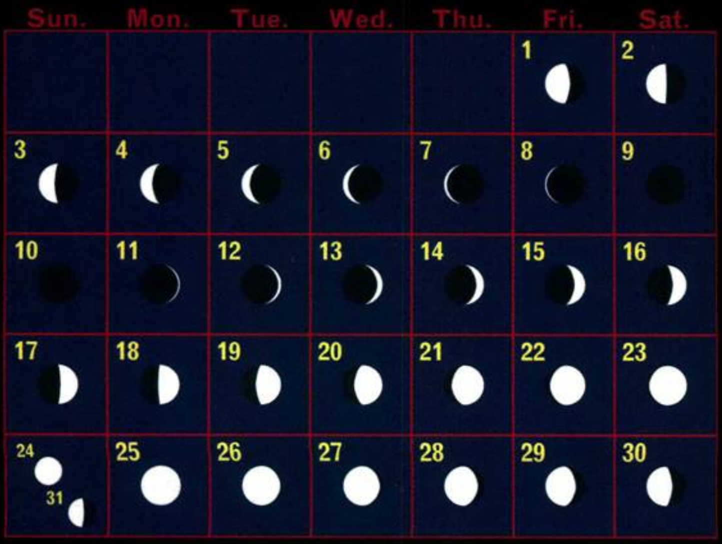
25 The moon passes 2° south of Saturn, 2 P.M. EDT

26 The moon is at perigee (224,284 miles from Earth), 8:58 A.M. EDT

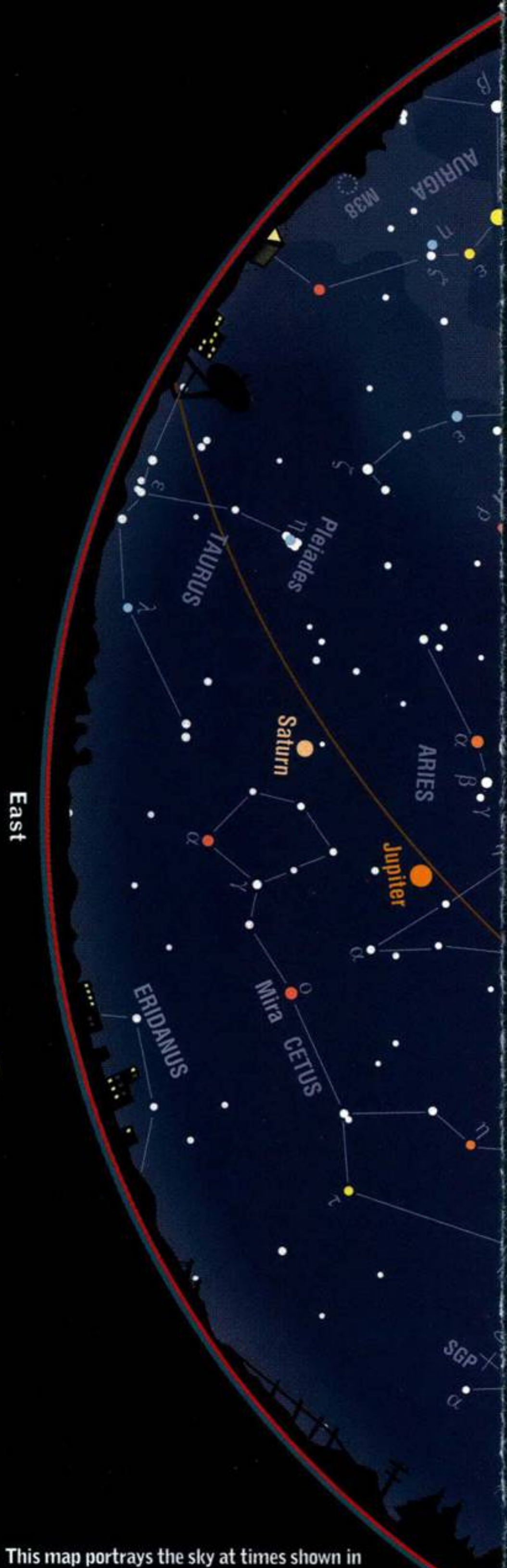
27 The moon passes 1.2° north of Aldebaran, 8 A.M. EDT

30 Venus is at greatest western elongation (46°), 8 P.M. EDT (page 73)

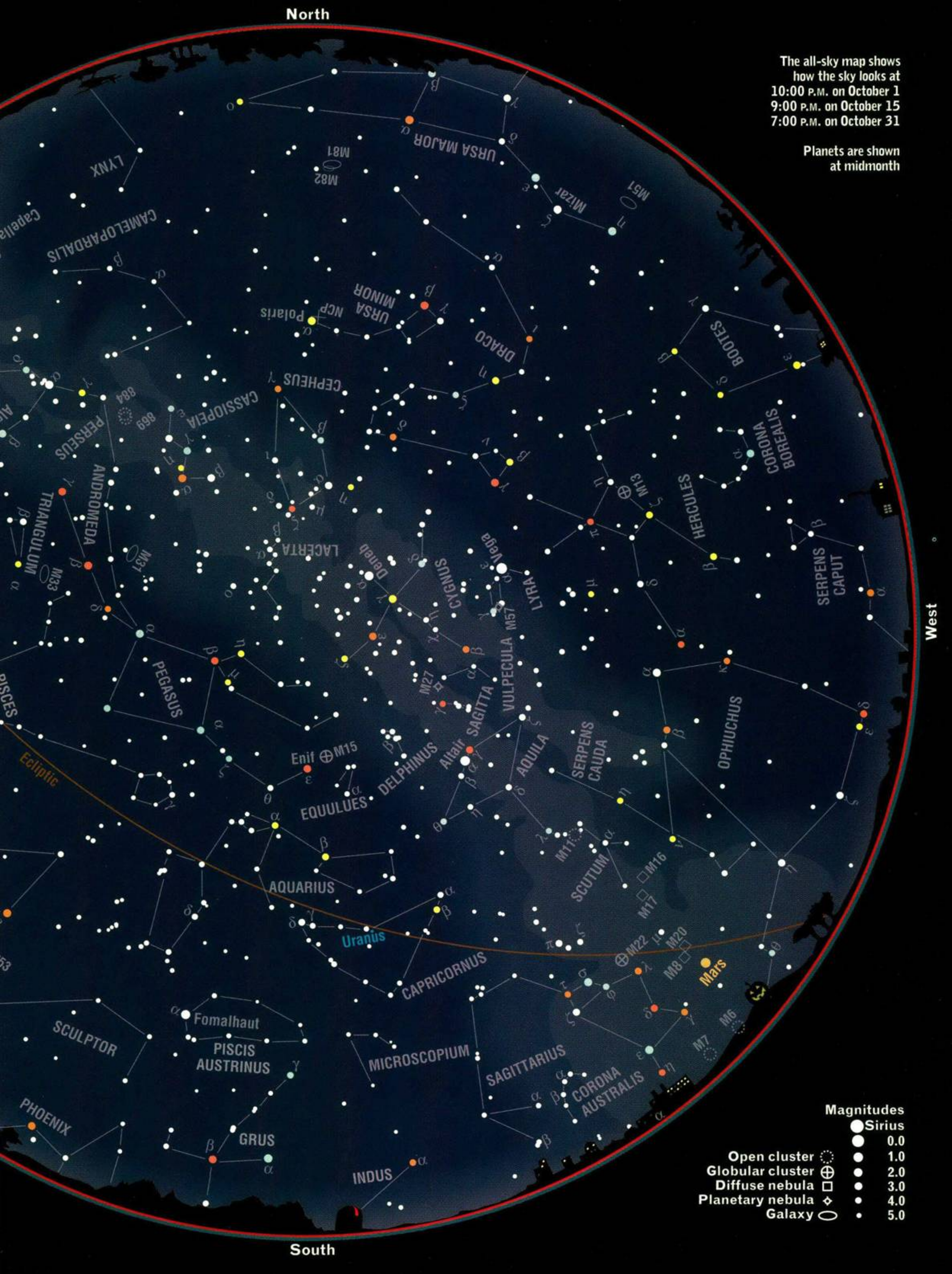
31 Last quarter moon is at 7:04 A.M. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 31	25	26	27	28	29	30



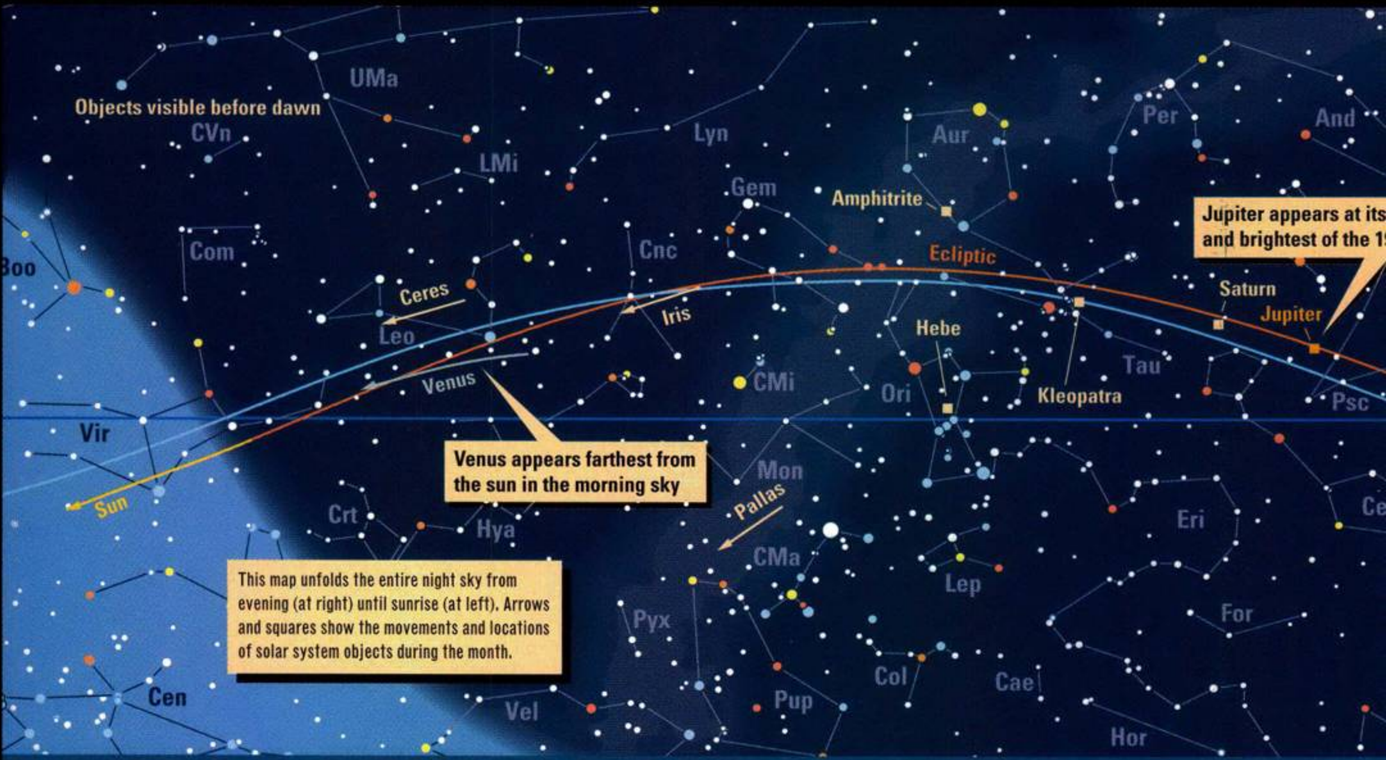
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


North
South
West
LYNX
URSA MAJOR
M81
M82
Mizar
M51
Capella
CAMELOPARDALIS
URSA MINOR
NCP
Polaris
DRACO
BOOTES
CEPHEUS
CASSIOPEIA
PERSEUS
884
869
CORONA BOREALIS
HERCULES
M13
ANDROMEDA
TRIANGULUM
M31
M33
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
SERPENS CAPUT
PEGASUS
PISCES
VULPECULA
M27
SAGITTA
OPHIUCHUS
Ecliptic
Enif
M15
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
EQUULUES
M11
SCUTUM
M16
M17
AQUARIUS
Uranus
M22
M20
M8
Mars
CAPRICORNUS
Fomalhaut
SCULPTOR
PISCIS AUSTRINUS
MICROSCOPIUM
SAGITTARIUS
M6
M7
CORONA AUSTRALIS
PHOENIX
GRUS
INDUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
10:00 P.M. on October 1
9:00 P.M. on October 15
7:00 P.M. on October 31

Planets are shown
at midmonth

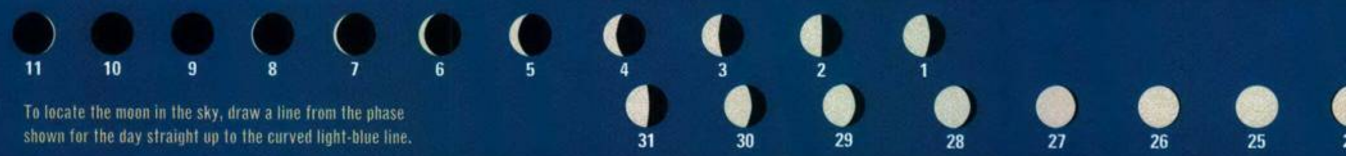
THE PATH OF THE PLANETS


UMa
Objects visible before dawn
CVn
LMi
Lyn
Aur
Per
And
Boo
Com
Gem
Amphitrite
Cnc
Ecliptic
Ceres
Iris
Leo
Saturn
Jupiter
Hebe
Venus
CMi
Ori
Tau
Kleopatra
Psc
Vir
Mon
Pallas
Sun
Crt
Hya
CMa
Eri
Ce
Lep
For
Pyx
Col
Cae
Cen
Vel
Pup
Hor

Jupiter appears at its
and brightest of the

Venus appears farthest from the sun in the morning sky

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


11
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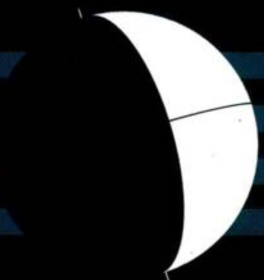
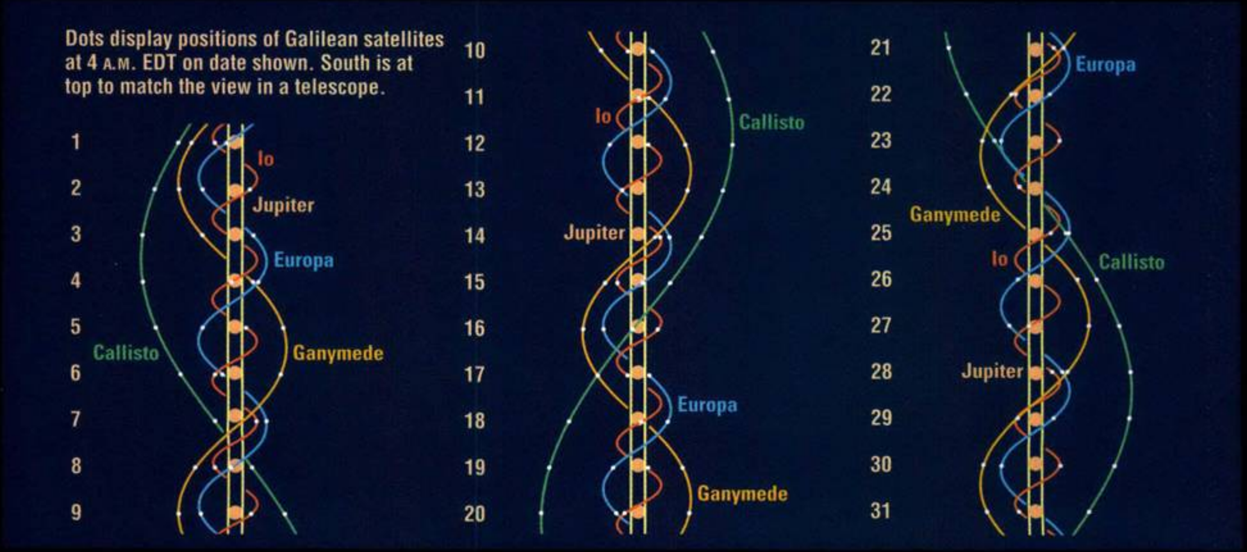
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

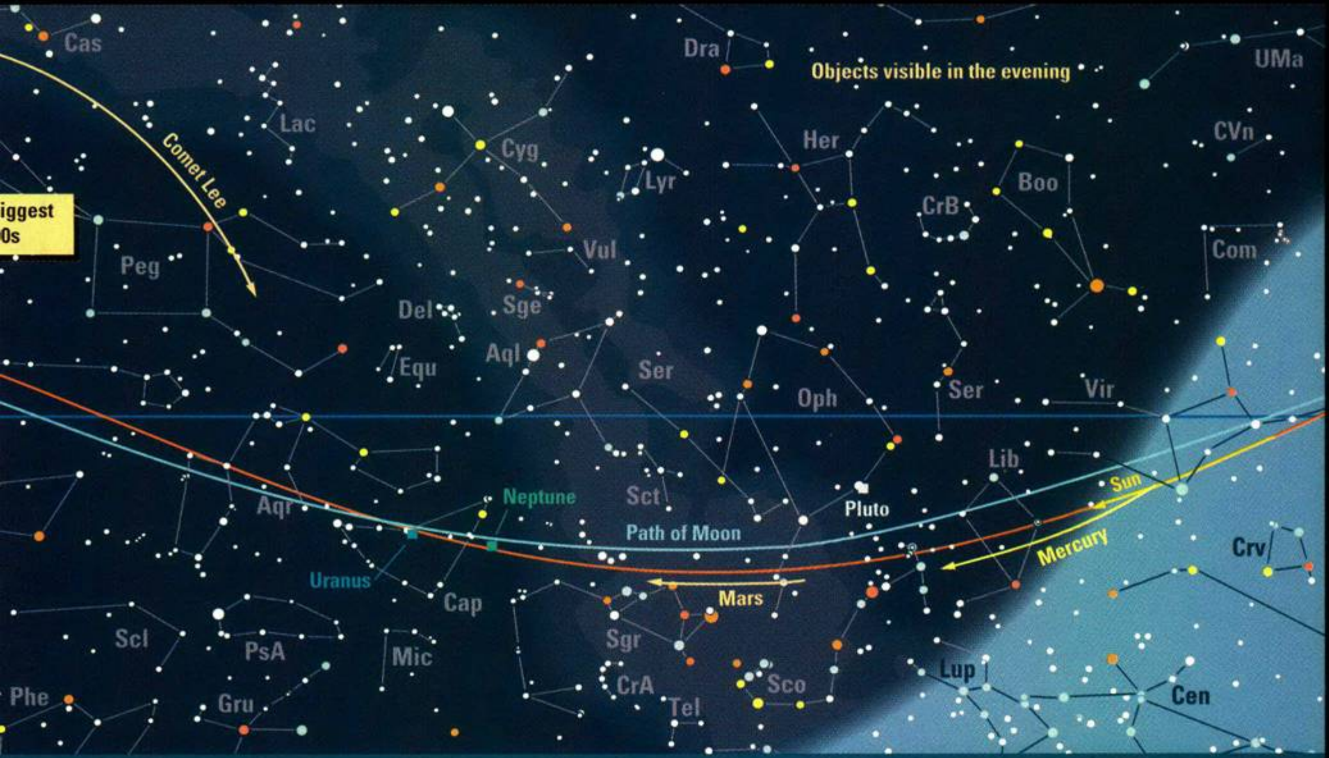


PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	October 1	October 31	October 1	October 31	October 15
Magnitude	−0.3	0.1	−4.5	−4.4	0.6
Angular Size	5.1"	7.5"	35.5"	24.1"	6.5"
Illumination	90%	48%	31%	51%	88%
Distance (AU) from Earth	1.327	0.896	0.470	0.691	1.431
Distance (AU) from Sun	0.462	0.391	0.724	0.720	1.394
Right Ascension (2000.0)	13h27.0m	15h49.0m	9h46.1m	11h26.0m	17h53.5m
Declination (2000.0)	−9°43'	−23°03'	9°37'	3°58'	−25°12'

JUPITER'S MOONS



Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.


Cas
Dra
Objects visible in the evening
UMa
Lac
Comet Lee
Cyg
Lyr
Her
CVn
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Boo
CrB
Vul
Com
Peg
Del
Sge
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Equ
Ser
Oph
Ser
Vir
Lib
Sun
Neptune
Sct
Pluto
Aqr
Path of Moon
Mercury
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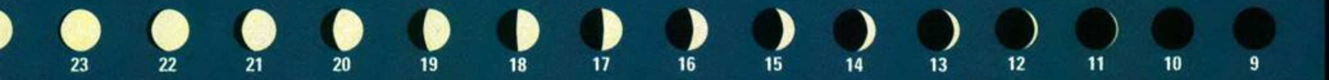
Tel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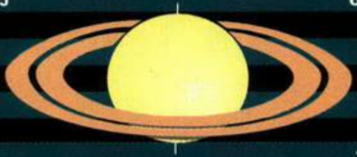
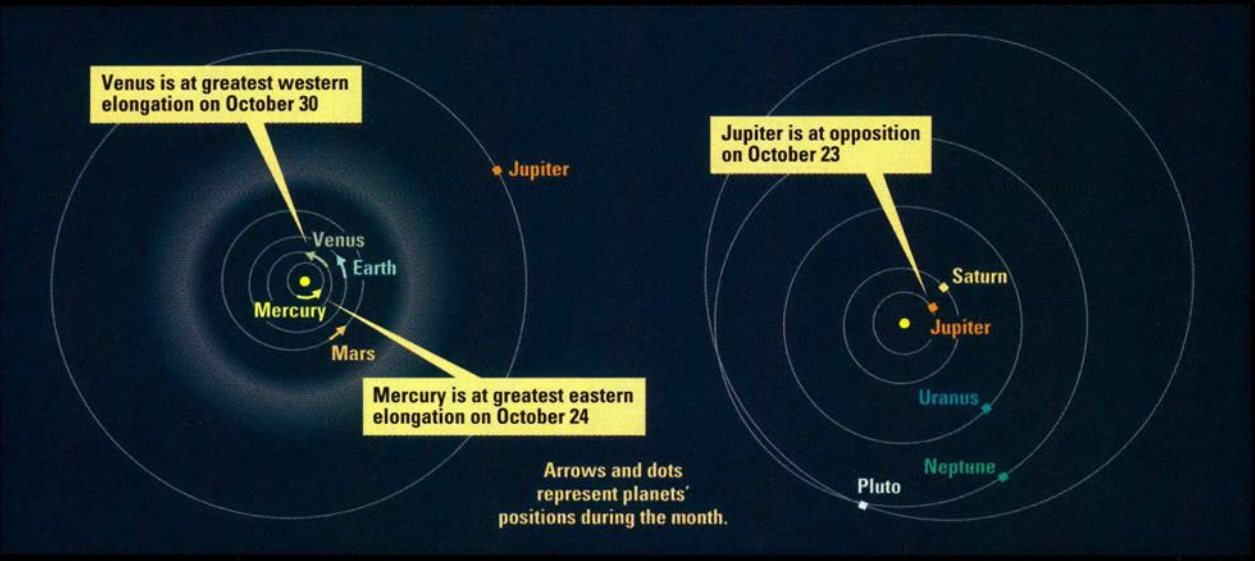


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
October 15	October 15	October 15	October 15	October 15
–2.9	–0.1	5.8	7.9	13.8
49.6"	20.1"	3.6"	2.3"	0.1"
100%	100%	100%	100%	100%
3.972	8.283	19.526	29.927	30.854
4.957	9.201	19.916	30.123	30.201
1h58.1m	2h55.0m	21h02.3m	20h15.1m	16h34.5m
10°25'	13°58'	–17°36'	–19°33'	–10°50'

THE PLANETS IN THEIR ORBITS


Jupiter
Venus
Earth
Mercury
Mars
Saturn
Jupiter
Uranus
Neptune
Pluto

Venus is at greatest western elongation on October 30

Mercury is at greatest eastern elongation on October 24

Jupiter is at opposition on October 23

Arrows and dots represent planets' positions during the month.

FIRST VIEWS: Planetary Nebula NGC 246

The 18th-century comet hunter Charles Messier could only see the brightest objects with his 3-inch refracting telescope. Just below the threshold of what he could see are a fair number of bright nebulae. One of these is NGC 246, a planetary nebula that often appears on "Top 100 NGC" lists. This quasi-circular shell of gas shows structure in moderate-sized telescopes.

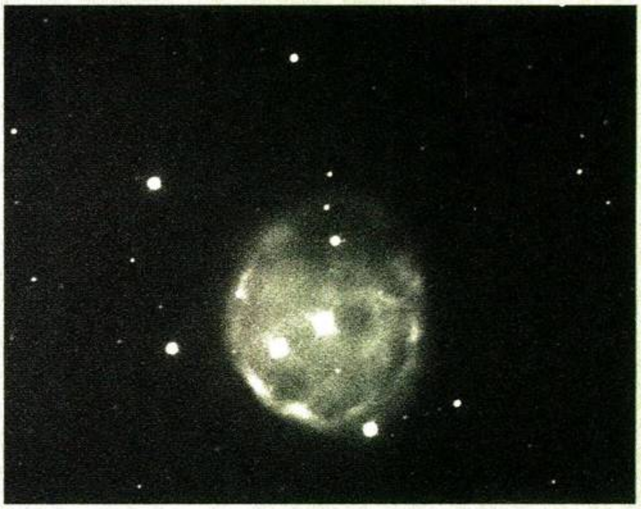
Using his 18-inch speculum (polished metal) mirror, Sir William Herschel found NGC 246. He described it as "four or five stars forming a trapezium of about 5' diameter. The enclosed space is filled with faintly terminated nebulosity. The stars seem to have no connection with the nebulosity." As a comparison, the Ring Nebula (M57) spans only about 1'.

Armed with a nebula filter, you can see more than the resourceful Herschel did. With a modern 6-inch reflector, the edges of this 4'-diameter cloud appear sharp while its face shows distinct irregularities. NGC 246's 12th-magnitude central star is a bit fainter than the nebula's total 10.9-magnitude brightness; the star can be spotted with an 8-inch or larger scope.

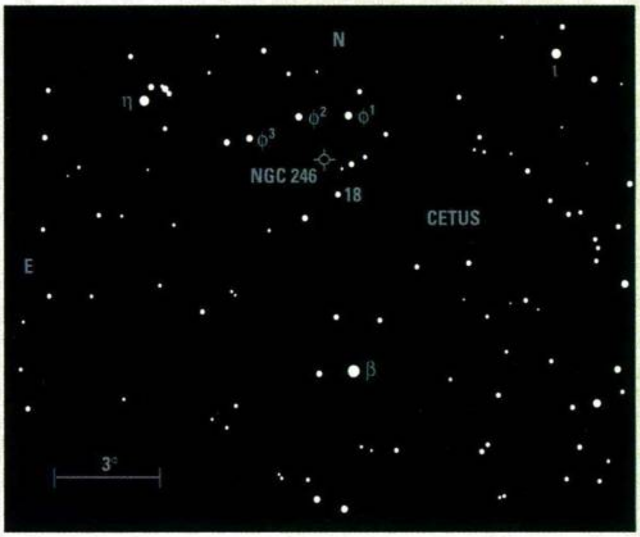
Try observing NGC 246 during the first week of October, when the moon is out of the evening sky and not splashing its light in front of the nebula. Also wait until after about 10 P.M. to allow the nebula to rise above the low-altitude atmospheric haze.

If you have the chance to look through a 12-inch scope or larger, don't pass it up. Take time to compare the view with and without a nebula filter. You'll find many knots of nebulosity in the filtered view. Remember to observe under a dark hood to combat stray light — the scourge of deep-sky observers.

Look for NGC 246 at 00h47.0m –11°53' (2000.0), just 6° north of the bright star Beta (β) Ceti. During the first week of October, Asteroid 92 Undina slowly inches nearby (see page 70).



Kim Zussman



Uranus is easier to find than Neptune, shining at a respectable magnitude 5.8. It lies less than a degree away from Theta Capricorni, a 4.1-magnitude star located in the northern part of the constellation. Voyager 2 targeted Uranus in 1986, and its disk was found to be almost completely featureless. Likewise, we see little on the disk through our earthbound scopes.

As Mars slinks below the southwestern horizon, the kings of the solar system, Jupiter and Saturn, dominate the eastern sky. **Jupiter** rises shortly after sunset and reaches opposition on October 23 (see "Falling for Jupiter and Saturn," page 90). During Jupiter's 12-year orbit around the sun, only once does it lie at its closest point to the sun (perihelion) when it is also at opposition, and this year is it. This makes Jupiter its brightest in a dozen years, at magnitude –2.9. Jupiter's retrograde motion takes it skimming along the border of Aries and Pisces. It crosses back into Pisces at midmonth while it closes in on 4.3-magnitude Omicron (ο) Piscium.

Jupiter remains above the horizon for more than 12 hours, offering observers with stamina for an all-night session a unique opportunity. The planet rotates in 9.8 hours, allowing a view of the entire globe as it rotates in a single night. Visible features in Jupiter's clouds move 36° of longitude per hour, so the dark and light spots change position noticeably within 30 minutes. Jupiter lies 368 million miles from Earth, but its physical size makes its apparent diameter nearly 50" across.

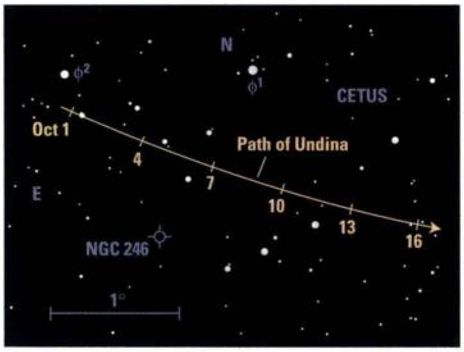
All this makes Jupiter a fine target for small telescopes. You'll see the Great Red Spot transit the planet's face as the giant storm extends its more than 300-year history. Fluttering in its wake like fireflies on a summer's evening, white spots and swirls follow the Red Spot, and other belts and zones carry their own subtle features. As with any planetary observation, the fine details are seen in brief moments of good seeing — moments when the air is particularly still — so take advantage of your patience and Jupiter will reward you in grand style.

Saturn is closing in on its opposition early next month and can be found a mere 15° east of Jupiter, roughly the width of your hand held at arm's length. Saturn rises approximately 40 minutes after Jupiter and is 13 times dimmer at magnitude –0.1. The Ringed Planet spends the month within Aries the Ram, north of Cetus the Whale. At 765 million miles from Earth, Saturn is twice as far as Jupiter. The planet's disk is only 40 percent the size of Jupiter's, but the long axis of the rings makes up most of the difference.

The rings are now on fine display, with the southern face tilted 20° away from edge on. Shining like an 8th-magnitude star, Saturn's major moon, Titan, orbits the planet every two weeks and is easily spotted in small scopes. The variable moon, Iapetus, appears brighter at western elongation and begins October to the east of Saturn shining at a dim magnitude of 11.9. Follow it throughout October. As it moves toward its western elongation on November 4, its brightness increases to magnitude 10.2. Iapetus passes due north of Saturn on October 16. It will be hard to spot in small scopes in early October but by month's end it will be easy.

As the giant planets rise higher in the sky, so too does fading Comet Lee (C/1999 H1). Now well past its best, the comet's placement high overhead around midnight does make it a

Asteroid of the Month: 92 Undina



All illustrations: *Astronomy*/ Elisabeth Rowan

Every now and then we get a chance to observe an asteroid that isn't in the normal "top 50." This month our target's orbit brings it slightly closer to Earth than normal. Undina, the 92nd asteroid to be discovered, is nearly as close to Earth as it can get.

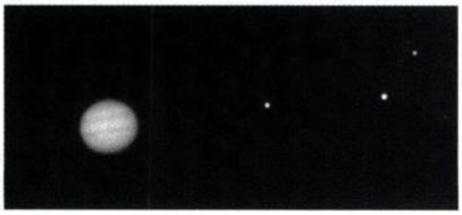
It should be easy to follow this 80-mile (130-km), 10.8-magnitude hunk of rock as it moves through the stars of Cetus. Undina lies 7° north of the bright star Beta (β) Ceti and, as fortune would have it, is nestled between the beautiful planetary nebula NGC 246 and two 5th-magnitude stars. A low-power eyepiece should reveal the trio.

For the first week of October, during the dark of the moon, Undina remains less than 1° away from the nebula. By the way, if you spy a comet-like haze between Undina and NGC 246, you've found the 12th-magnitude spiral galaxy designated NGC 255.

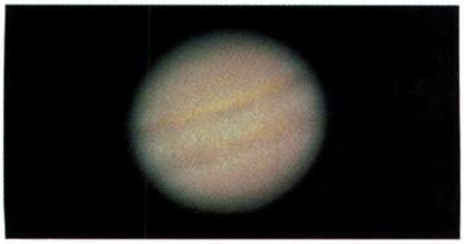
Jupiter Shines

In the last decade, Jupiter has never been better. Firstly, kingly Jove reaches opposition on October 23, meaning it rises near sunset, crosses high in the south at midnight, and sets near sunrise. Secondly, Jupiter itself is near the perihelion (closest point to the sun) of its slightly elliptical orbit. This also means it's closer to Earth and its disk will appear bigger and brighter.

At magnitude –2.9, Jupiter is at its brightest in years. Six years from now, it will only reach magnitude –2.4, still bright, but not as dazzling. Those not familiar with the sky may mistake Jupiter for Venus, which is currently blazing in the morning sky.



Chris Flynn



Tom Murdic

You can watch the stately parade of the four Galilean moons around Jupiter in any size telescope and even in larger binoculars. A 4-inch scope will easily reveal the two main cloud belts. As your eyes become familiar with Jupiter's features, you will begin to see more detail in the clouds. Practice does indeed make perfect.

Lots of action happens near month's end. On the night of October 24, the full moon floats about one binocular field below Jupiter, while Saturn follows not too far behind. The visibility of these two bright planets in the evening sky allows you to do some sidewalk astronomy on Halloween. Give those ghosts and goblins a real treat by showing them Jupiter and Saturn through a telescope.

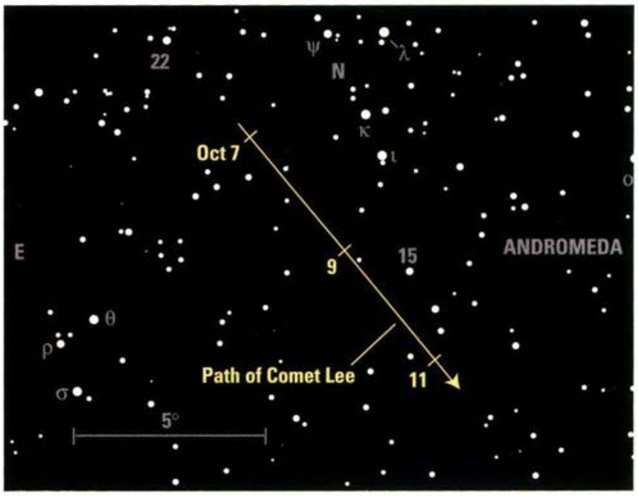
On the evening of October 28, observers east of the Great Lakes will be treated to a special double shadow transit. At 7:05 P.M. EDT, the small shadow of Io will appear on the eastern side of the planet's disk. It will join Ganymede's shadow, which then lies on the other side of the disk. Ganymede's shadow leaves the planet at about 7:40 P.M. EDT. See "Falling for Jupiter and Saturn" on page 90 for more detailed information.

Comet Lee Continues!

Summer's surprise comet (C/1999 H1 Lee) rises quickly into the northern circumpolar sky this month, meaning that it is above the northern horizon all night. The one thing dampening the festivities is the Hunter's Moon. Because the Hunter's Moon rises only tens of minutes later each night after full moon, we have to be patient to get a good look at Comet Lee under dark skies.

Deep-sky observers will be glad to know that Comet Lee passes only 1° north of NGC 147, one of the dim satellite galaxies of the Andromeda Galaxy (M31), around October 3. Predicting a comet's brightness can be tricky, but Lee will certainly be easier to spy than NGC 147. The galaxy has a condensed nucleus but a large, faint halo of light glowing at magnitude 9.3 that appears much dimmer. Use low power to compare the two, then boost the magnification to see detail.

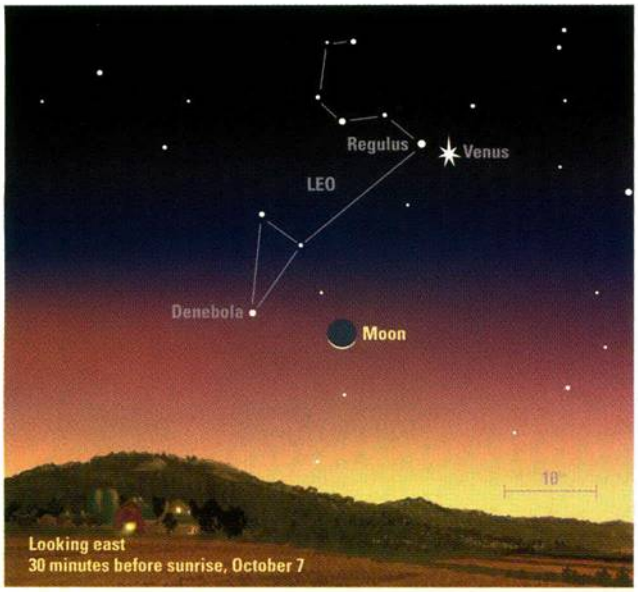
Comet Lee will be easy to find on the nights of October 18 and 19, when it lies only 1° to the northeast of the bright star Beta (β) Pegasi. The Great Square of Pegasus is high in the south at midnight, and Beta Pegasi is the top right star of the square. For the rest of the month, the comet reduces speed while passing through galaxies in Pegasus. The chart will help you locate Comet Lee during the dark-sky window at the beginning of the month.



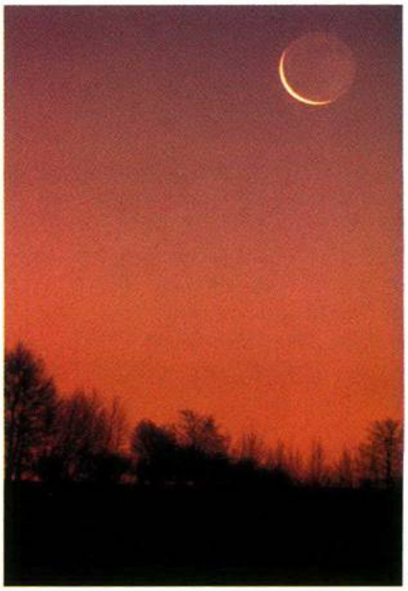
Young Moon in the Old Moon's Arms

Few sights are as lovely as a thin crescent moon's gray ashen light. From the moon's point of view, Earth is at this time awash in almost full sunlight. This sunlight reflects back to bathe the unlit face of the moon. The "new moon in the old moon's arms" is a poetic phrase used to describe this earthshine.

The morning of October 7, about 45 minutes before sunrise at roughly 6 A.M., offers the opportunity to see such a crescent. If you're up to a moderate challenge and have an eastern horizon clear of trees and buildings, look for the thin Cheshire smile of an even slimmer crescent one day later, on the 8th. Luna will then be only 25 hours away from its new phase. From the West Coast, it will be even thinner and only 22 hours away from new.



Looking east
30 minutes before sunrise, October 7



Alan Dyer

During January mornings, the old moon's path stays low to the horizon, obscuring the crescent. In October the path is steeply inclined to the horizon, making it much easier to see this old moon. Start 45 minutes before sunrise and scan just above the horizon with binoculars. Trace a line from Venus down to the horizon; the thin crescent will rise two to three binocular fields to the left of that point.

Observer's Challenge: Uranus

Uranus never fails to surprise the newcomer to backyard astronomy. At a bright magnitude of 5.8, its green glow in an 8x50 finderscope makes the planet stand out against the backdrop of stars. Uranus isn't a popular observing destination. You can't simply swing your scope toward it, like the classic bright planets. Yet, given the right conditions and some patience, you can find Uranus without optical aid from a dark-sky site.

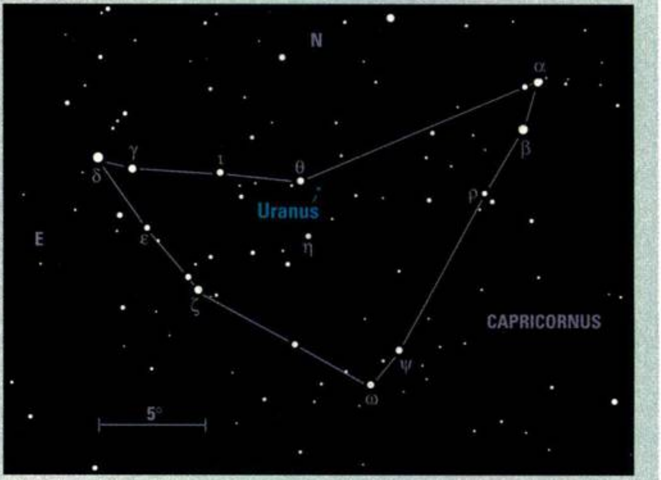
Through a small scope at low power, Uranus looks decidedly different from any star — its green hue forever impresses me. The planet's diminutive diameter is just under 4", one-tenth the size of Jupiter.

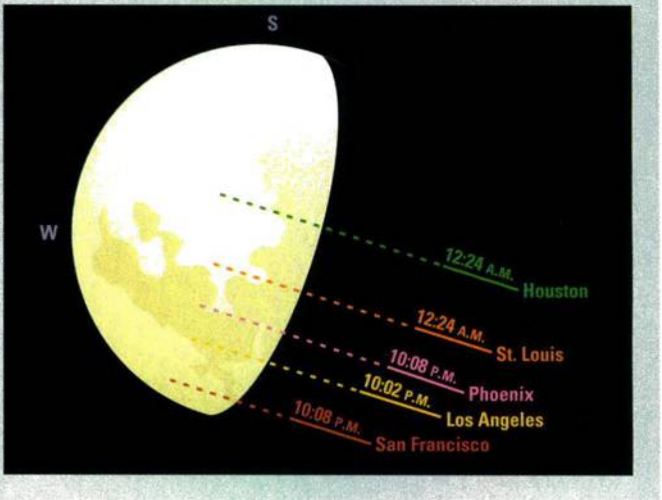
This month, Uranus is a challenge to find because there are no bright stars to lead the way. However, on the night of October 18/19, the first quarter moon passes in front of Uranus for the central and western United States. With the exception of those in the Winnipeg area, Canadian observers will at best view the moon sliding past the planet to the south.

Observers living east of a line from Chicago to Florida shouldn't feel left out, for you can moon-hop to Uranus. At 8 P.M. EDT, aim your scope just north of the moon's center, then slide 10 minutes of right ascension (5 moon diameters) to the east (left) and you're there.

Since Uranus is not a distant star, it will fade as the moon covers it, instead of winking out in an instant. From the Great Plains, the planet disappears at roughly 12:20 A.M. CDT, while on the West Coast the occultation begins at roughly 10 P.M. PDT. The planet's reappearance on the bright limb will likely go unseen.

Keep in mind that this may not be a spectacular event. The moon's brightness will hurt visibility. Even so, it's tough to resist observing such an occultation.





natural target during a night of observing. Comet Lee shines at magnitude 8.9 in Cassiopeia on October 3, when it lies some 8° north of the Andromeda Galaxy (M31). By October 19, it has dimmed a whole magnitude and passes 0.7° west of the star Scheat (Beta [β] Pegasi). Although the comet glows dimly, a bright, nearby star will provide a useful guide to its position.

The summer constellations slowly give way to those of autumn. Aquila the Eagle leads the descent toward the western horizon followed by Cygnus the Swan in its graceful dive from the starry scene. Vega swings low to the northwest by late evening as the Big Dipper prepares to swing up around Polaris, the pole star. High overhead many star clusters are scattered throughout Cassiopeia and Perseus. Watch Beta Persei, better known as Algol, dip in brightness on October 2 and again on the 19th, 22nd, and 25th. The prototypical eclipsing binary fades every 2.87 days — only some of the eclipses are visible during the night from any one location.

Fomalhaut, the brightest star in the constellation Piscis Austrinus the Southern Fish, stands high in the south. It can easily be found by tracing a line from the right-hand side of the square of Pegasus toward the southern horizon. Halfway to Fomalhaut, you cross the region of Aquarius the Water-bearer.

East of Aquarius stands Cetus the Whale. This month Cetus appears to have a new star. Saturn is in the region and acts as a guide to find the variable star Mira. Mira is another prototypical star, but instead of an eclipse causing changes in brightness, Mira's size physically changes with semiregular pulsations. At roughly magnitude 9 in July, Mira has been brightening steadily during the past few months. It is predicted to peak around November 5. It typically reaches magnitude 3.4, but the star has been known to exceed this by a magnitude or more. Watch Mira carefully this month and the next to see what surprises it has in store this year.

By midnight, Taurus the Bull clears the eastern horizon. The chill of the October night air hints at the forthcoming winter, and the bull confirms the impending cold snap. The bright constellations of summer are receding in the west, and the equally brilliant stars of winter are bristling along the eastern horizon. The dimmer stars of autumn rest in between and may not glitter as brightly as these other seasonal beacons, but there are many treasures to explore.

For a tough target, try **Pluto** at magnitude 13.8. This month, it lies very near another solar system object, the asteroid Juno. On the 5th, the pair is less than half a degree apart in Ophiuchus. A detailed star map will be necessary to identify both. Juno shines at a dim magnitude 11 — faint, yet a lot brighter than Pluto.

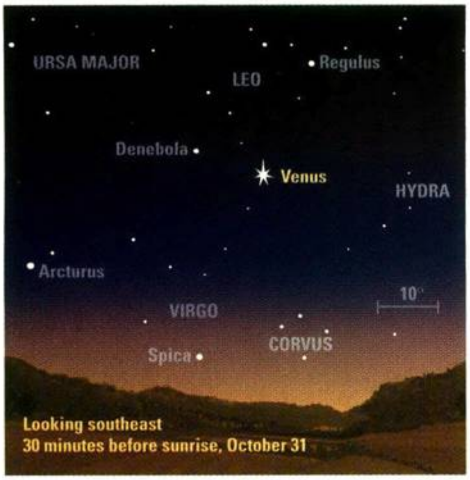
The Hunter's Moon on October 24 affects viewing of this year's Orionid meteor shower. Caused by one of two yearly streams linked to Halley's Comet, the Orionid shower peaks around October 22. The overwhelming brightness of the moon will leave only the most spectacular members of the shower visible to stalwart observers.

In the predawn sky of October 5, a slim crescent moon rises shortly before 4 A.M. local time. It's followed an hour later by brilliant **Venus**. The planet rises with Regulus, the brightest star in the constellation Leo the Lion. Between October 7 and 9, Venus lies less than 3° from Regulus, providing a spectacular sight. Venus shines at magnitude –4.5 and has a phase that grows from a crescent to 50 percent lit at month's end. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

Venus Shines Brightly in the Morning Sky

Just last month, our sister planet bolted out from behind the sun into the early morning sky as it overtook Earth on the orbital racetrack. Now Venus assumes a commanding role in the southeastern sky.



Looking southeast
30 minutes before sunrise, October 31

Venus reached its greatest brilliancy on September 26, at magnitude –4.6. Through a spotting scope, you could see a thick crescent shape illuminated 38 percent. By the end of October, Venus will be at its highest elevation above the horizon and have fattened into a half phase.

The best time for observing Venus with the naked eye is early in the month. On October 5, the waning crescent moon stands almost 7° (slightly more than one binocular field) above the blazing planet. Then from October 7 to 9, the blue-white star Regulus lies less than 3° to the left of the planet.

As Earth swings around the sun, the background stars appear to pull upward, away from the eastern horizon. This motion will carry Regulus to 5° above Venus by October 13. Don't forget to seek out the thin old moon on the morning of October 8 (see "Young Moon in the Old Moon's Arms," page 71).

Saturn's Splendor

Each day Saturn rises earlier in the evening. If you want a good look at its rings and intriguing cloud-top markings, you must wait until the planet is high in the southern sky.

At the zenith (the point directly overhead), light travels its shortest path through our atmosphere. The lower we look in the sky, the more air and turbulence we must look through. "Good seeing," or very little turbulence, is the key to great views. Your best chances come after 11 P.M.

The planet's rings tilt at a 20° angle relative to Earth, making them much easier to see than last year. Look for a fine black line, called Cassini's Division, that splits the rings. Can you detect the slight color and brightness difference between the inner and outer rings?

Note the shadow the planet casts on the rings. By November 6, Earth rests between Saturn and the sun so the shadow will disappear. Saturn's shadow helps give the planet that 3-D look. Saturn's terminator (day-night line) may also be visible. Look for the edge of the cloud tops near the shadow to be slightly less in focus than the cloud tops on the unshadowed side.

Jack Newton

Although often overlooked by backyard observers, Saturn's moons are also worth a look. They don't appear as spectacular as Jupiter's Galilean satellites because they don't appear in a straight line. However, a 6-inch scope can easily reveal the five brightest: Tethys, Dione, Rhea, Titan, and Iapetus.

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By Philip S. Harrington

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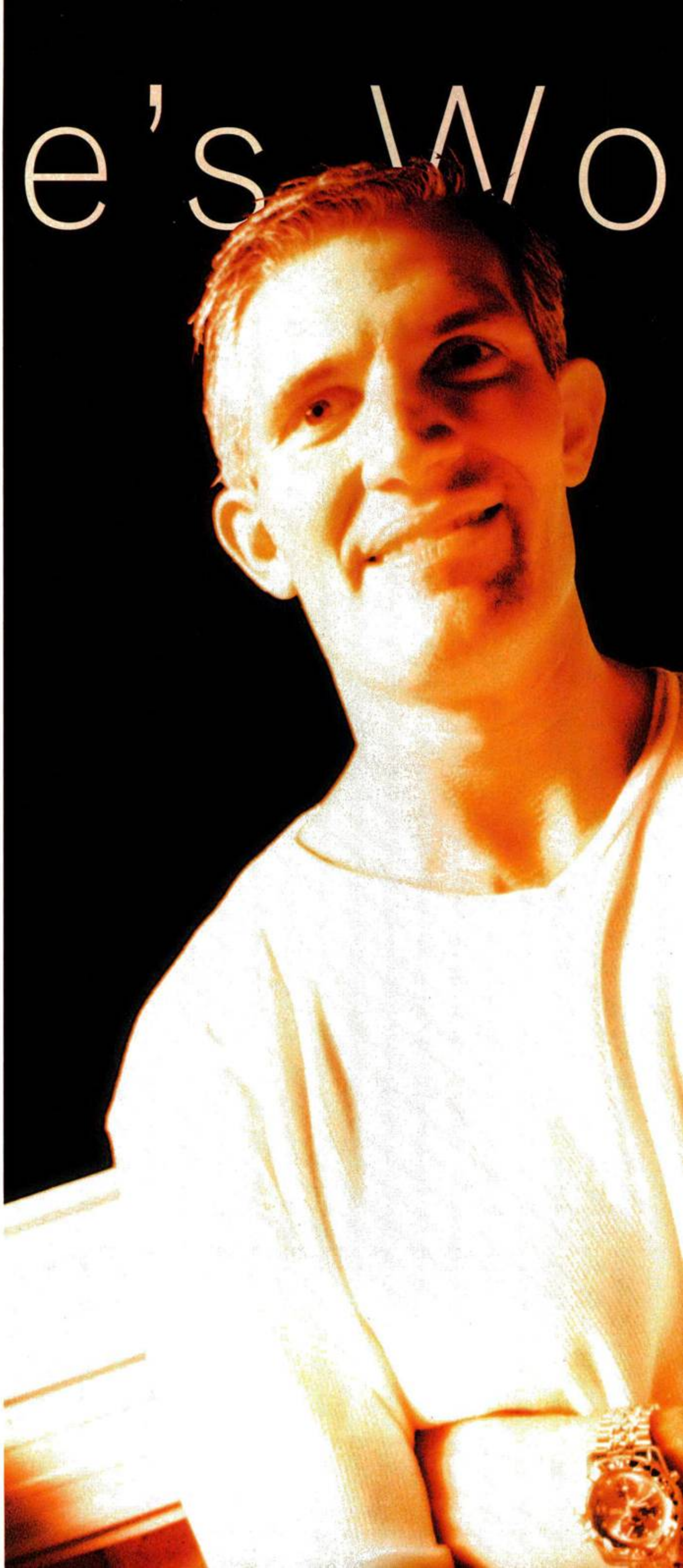
Ware's Wo

Move over, CCDs — old-fashioned film isn't dead yet.

by Robert Reeves
Astronomical images by Jason Ware
portraits by Randy Anderson



The observatory roof slowly rolled back, flooding the formerly dark room with sunlight. As my eyes adjusted to the sudden brightness, the gleaming white Meade 12-inch Schmidt camera seemed to awaken and beckon for a loving touch. As I ran my hand over its cannon-like barrel, I couldn't help but reflect on the maturing of amateur astrophotography over the four decades that I have practiced this art. The amateur can now routinely operate powerful large-aperture Schmidt cameras, once only the realm of professional astronomy, and produce exquisitely detailed wide-field celestial images that rival those from professional instruments.

One person who routinely does such astrophotography is Jason Ware. He operates a 12-inch Schmidt camera from his Wild Duck Observatory, located a 90-minute drive north of his Dallas, Texas, home. From this 12 by 12-foot observatory, Jason enjoys 6th-magnitude skies while imaging not only the showcase objects and faint targets, but also wide-field groups of objects, making high-resolution images suitable for framing.

rld

At age 37, Ware is a youngster in the field of advanced astrophotography where practitioners are typically older. Jason considers it an honor to use the large Schmidt. Noted mainly for his astrophotography, Jason is also an avid visual observer, having earned his Messier and Herschel certificates. But in astrophotography, where beginners are ecstatic to achieve any image at all, Ware has become such a perfectionist that he considers each of his twice-monthly photo sessions a success if he achieves only one publication-quality image. On average, he actually obtains three completely successful images per trip.

I have used a smaller 8-inch Schmidt camera for the past 20 years and was eager to get my hands on the larger 12-inch camera. I was thus delighted to accept an invitation by Jason to accompany him to his observatory for an evening with the optical marvel. I was equally anxious to see how he processes his exceptional images, because unlike many of today's skyshooters, Ware does not digitally enhance his celestial pictures. Although he has recently started doing some digital imaging, most of Jason's work is prepared entirely the old-fashioned way, in a photographic darkroom.

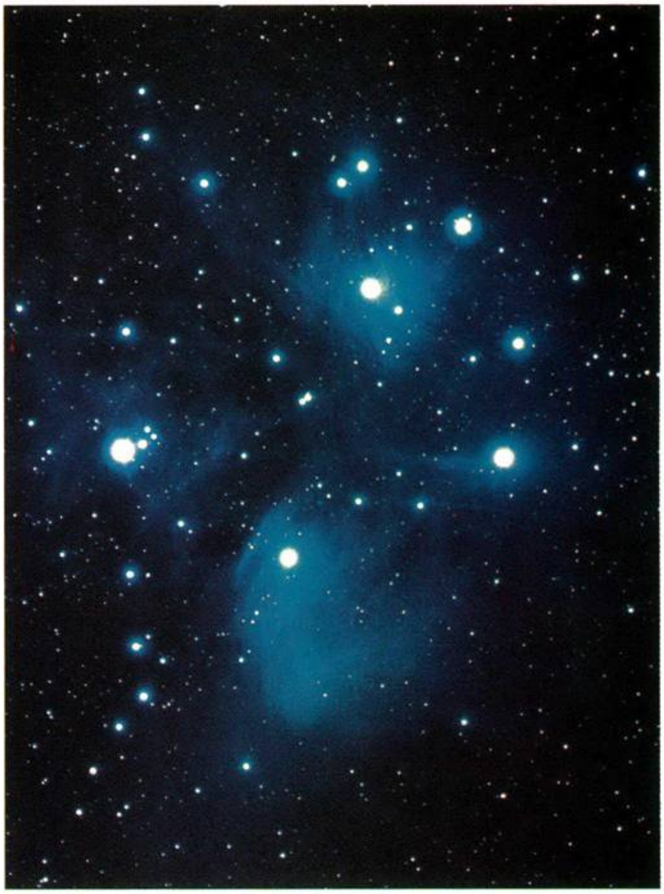
Using the Schmidt

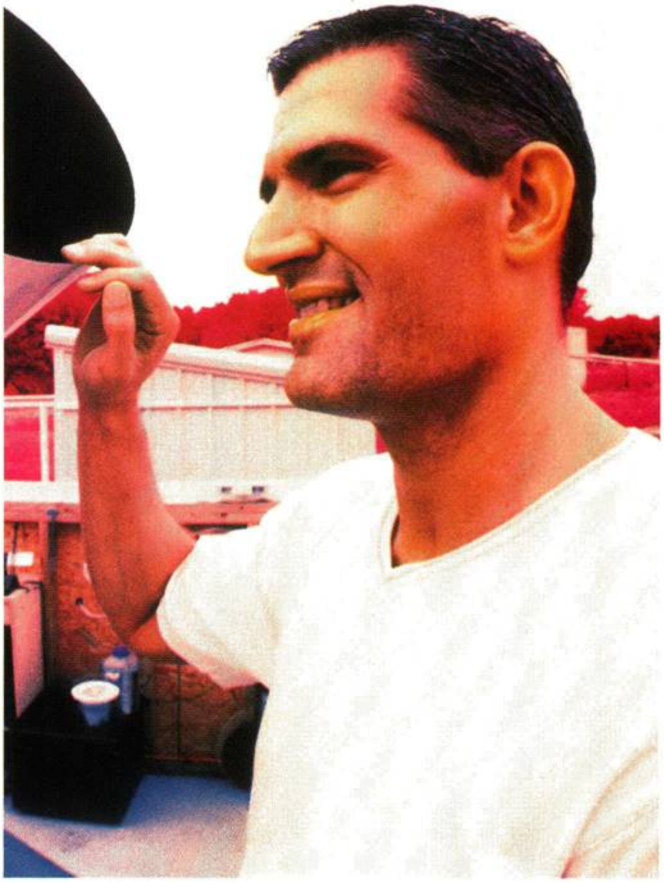
The 12-inch camera Jason uses is a true Schmidt design like the famous 48-inch Schmidt on Palomar Mountain in California. The camera possesses a focal length of 670 millimeters and operates at f/2.2. This produces a 4.5° by 5.5° field of view on a 6 by 7-centimeter negative using 120 format film. The camera uses single exposure film "chips" that must be individually loaded into the camera's film holder. The holder is then magnetically mounted at the camera's focus through a door which opens on the side of the tube.

Being a true Schmidt, the primary mirror is larger than the corrector plate, spanning 16 inches to the corrector's 12 inches. This gives the camera a distinctive step-tube appearance in contrast to the straight tube of the classic Celestron/Epoch Schmidt which uses an equal-sized corrector and mirror. The corrector is smaller by design to eliminate vignetting of the extremely wide field. Since the corrector must be mounted twice the instrument's focal length from the mirror, the 12-inch Schmidt is a long instrument compared to a regular Schmidt-Cassegrain telescope.

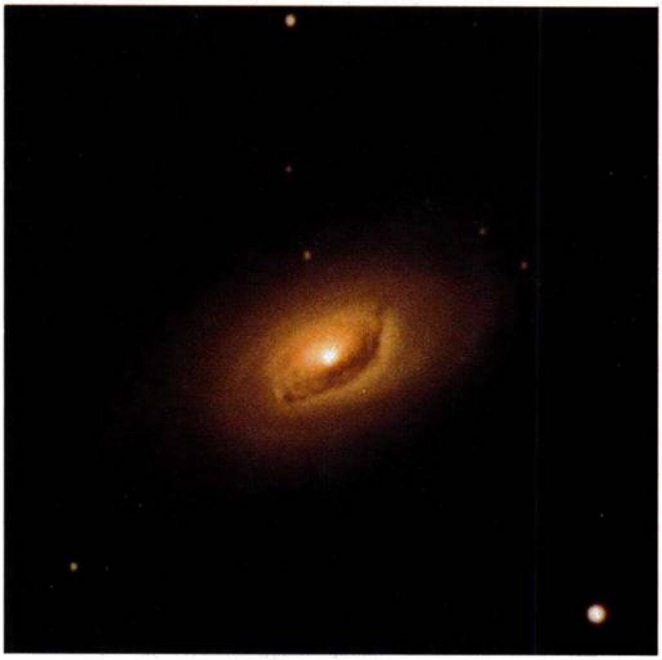
The huge Schmidt is carried on an equatorially aligned Meade 16-inch SCT LX-200 fork mount that is more than adequate for the camera and its refractor guidescope. Although the camera normally comes with a 7-inch guidescope and CCD autoguider, Jason deliberately chose to use a smaller 5-inch f/9 guidescope so it could be mounted off-axis in adjustable Losmandy rings. This allows him to center comets in the Schmidt's field of view while guiding on the nucleus. He has recently added a larger, stiffer set of rings that enables using filters during long exposures.

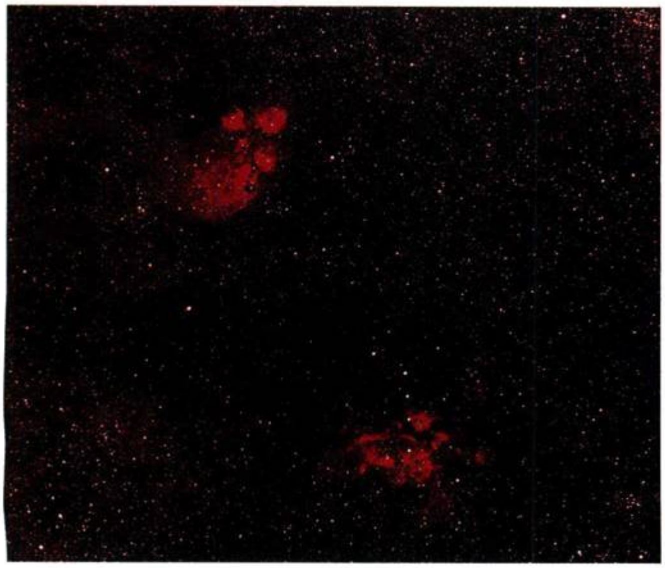
To locate his target fields, Jason uses a transparent template which he lays over the pages of the *Uranometria 2000.0* star atlas. Because the magnetically mounted Schmidt film holder can be rotated to any framing angle, multiple objects can be oriented as needed within the field.





The Orion Nebula (M42) appears in a composite of four 60-minute exposures taken with a 6-inch f/9 refractor. Above right: The Pleiades (6-inch f/9 refractor, composite of two 60-minute exposures). All images use Fuji HG 400 film (120 format).





Once the Schmidt is properly aimed at the desired celestial coordinates, an easy task with the LX-200 controls, the camera's large size often makes it awkward to reach the film loading door. To make it easier to install the film holder, the Schmidt's controls have been modified to include the "load" command. When invoked, this command will slew the camera from the desired direction to a position where the film loading door on the side of the tube is easily reached. Once the film is loaded, the controls automatically reposition the camera's aim on the original celestial coordinates.

Stray light, even from feeble LED displays, can noticeably fog today's high-speed color emulsions. The film is most prone to fogging while loading the camera's film holder. Jason performs this operation in a light tight-box on one wall of his observatory, but he has found that circumstances can still conspire to fog the film unless precautions are taken. Black tape is used to cover the LEDs on the telescope mount while other illuminated devices such as the music CD player, battery charger, and autoguider controls are covered. Jason even changes into all-black clothing to prevent stray light from reflecting off himself and onto the film holder while he is handling it. The latter results in a scene reminiscent of "Ninja Astronomer," but Jason's end results justify his efforts.

Humidity more than stray light is actually the film's chief enemy. Because the 120-format film used in the 12-inch Schmidt has such a large surface area, it can actually swell and buckle if it absorbs moisture from the air during the exposure. This will ruin the critical focus achieved by the Schmidt mirror optics. To combat the humidity problem, Jason uses the same trick I popularized 10 years ago with my Schmidt camera; he floods the interior of the camera with a continuous slow flow of dry nitrogen gas. To stabilize the film before use, Jason bathes the emulsion in the same atmosphere it will encounter inside the camera and even purges the film-loading dark box with nitrogen. This will prevent moisture from warm hands from degrading the hypersensitized film emulsion.

A number of different films are used in the Schmidt, including Kodak's Ektar 25, PPF 400, Technical Pan, and Fuji 400. Jason hypers his own film using an Edmund micron-range vacuum pump, a homemade hypering chamber heated with a modified Radio Shack temperature alarm, and 8 percent forming gas. He vacuums color film for 30 minutes before hypering while black and white receives 60 minutes of vacuum, followed by three-PSI forming gas at 48° Centigrade. His hypering times for Kodak PPF and Ektar 25 are 3 and 12 hours, respectively.

Image Enhancement Technique

The real secret of Jason Ware's astrophoto success is in the stack and copy technique to enhance the images. In this process, Jason actually shoots three identical images of each target. The two best exposures are then selected for negative stacking. For this process, each image is exposed to a point just short of where sky fog begins to show on the negative. With Jason's current film of choice for the Schmidt, 120-format Ektar 25 (which he laments will soon be discontinued

Opposite page: The Eagle Nebula (16-inch SCT, composite of two 60-minute exposures). Top left: NGC 6960 (6-inch f/9 refractor, composite of two 75-minute exposures). Left center: M64 (16-inch SCT at f/10, 60-minute exposure). Left: NGC 6357 and NGC 6334 (12-inch Schmidt camera, composite of two 5-minute exposures).

Enhancing Images the Ware Way

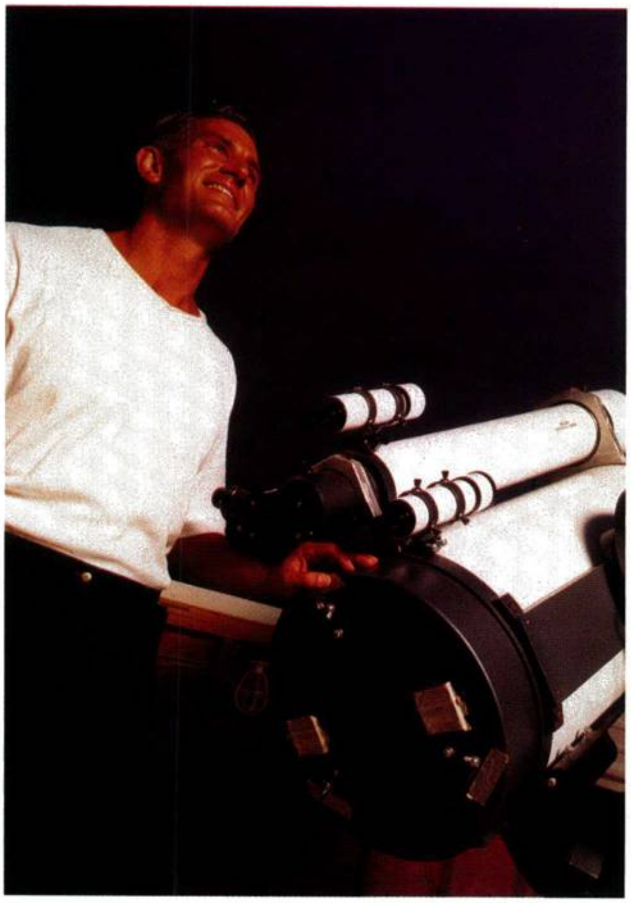
Here are the photographic steps Jason Ware takes after the initial celestial exposure to produce the colorful, high-contrast, detailed astrophotos he is noted for:

Step 1. Process the single-exposure Schmidt camera medium-format film "chips" in a motorized print processing drum.

Tip: When developing the single-frame "chips," care must be taken to prevent the film from overlapping on a reel and ruining the negatives.

Step 2. Sandwich two original negatives taken with the Schmidt camera. Tape the edges of the films to hold them in place before permanently securing them with dabs of superglue.

Tip: The trick is to use high magnification to ensure the two negatives are exactly registered with each other. Ware uses a Radio Shack 30x pocket magnifier to guarantee tiny stars overlap perfectly.



Step 3. The resulting negative sandwich is projected onto 4" by 5" Kodak Type 4111 print film with a color enlarger. The color correction settings must be determined experimentally, but if all factors are the same, future copy work will use similar settings.

Note: Type 4111 is the same emulsion as 35mm Type 5052 and is developed in standard Kodak C-41 chemistry. This film has no orange base and is used to make high resolution transparencies from negatives.

Tip: Make two underexposed Type 4111 transparencies, each of which is just light enough that when they are stacked, registered, and glued together, they have normal density. Type 4111 film is so slow that the required enlarger exposure is often one minute. Any required dodging and burning are done during this step.

Step 4. The stacked transparencies are then contact printed onto 4" x 5" Kodak Commercial internegative film.

Tip: Since Type 4111 film has a much thicker base than 35mm film, the two stacked emulsions are separated by a distance sufficient to cause parallax between the tiny star images. Ware eliminates this on the internegative by exposing the contact print stack with the enlarger raised to its maximum height so the light path through the film stack on the enlarger base board is as perpendicular as possible.

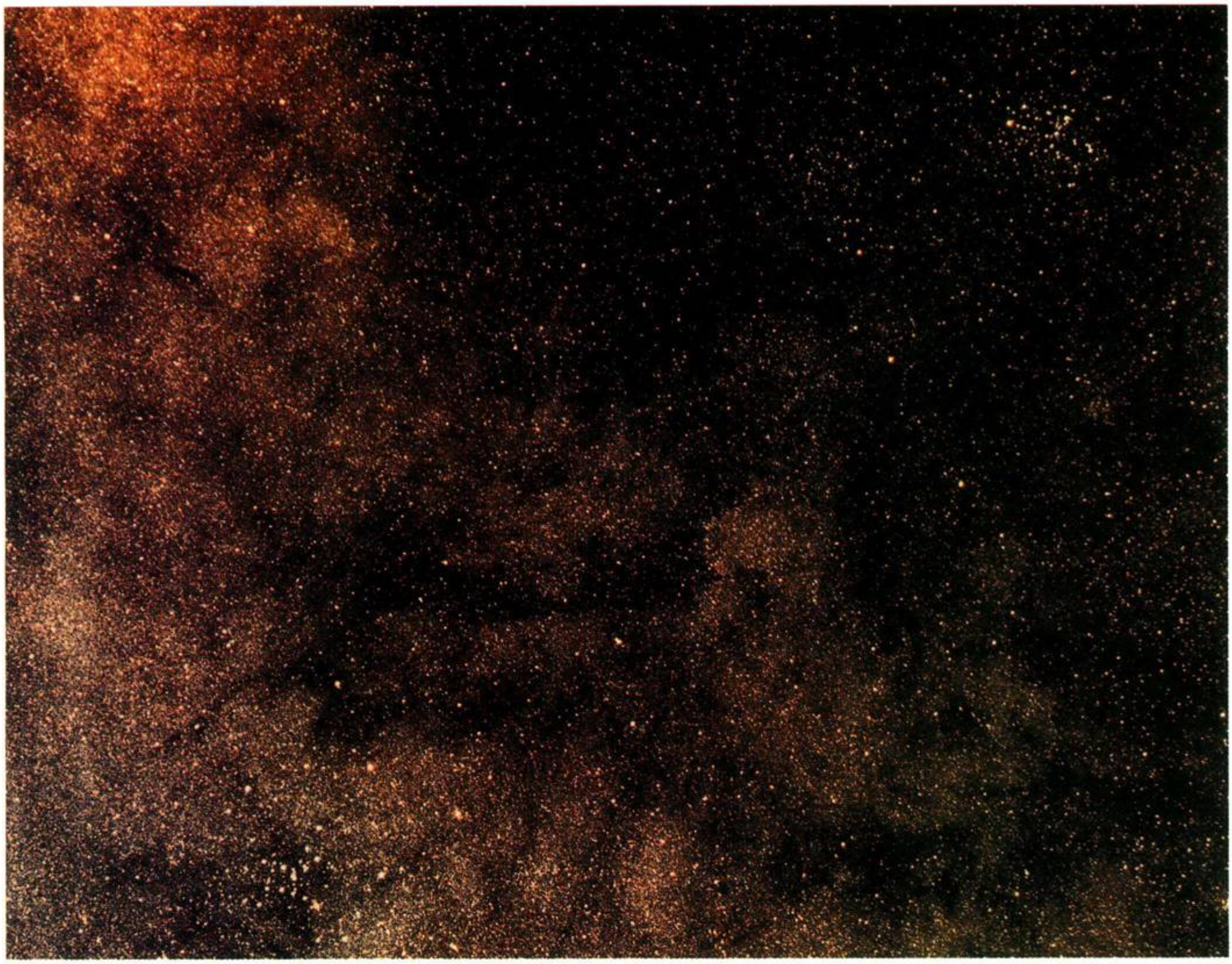
Step 5. The internegative is then printed onto Kodak Ultra paper.

Tip: With weak images it's necessary to stack two internegatives, as in Step 1, to achieve high enough contrast. The final print is a straight print from the internegative.

Oh Ware, Oh Ware, on the Web?

Both Jason Ware and author Robert Reeves maintain websites devoted to astrophotography. To visit their worlds online, point your browser to:

Jason Ware: http://www.galaxyphoto.com/ • Robert Reeves: http://www.connecti.com/~rreeves



by Kodak), the exposure is 17 minutes. Each exposure is not as dense as a single negative can be, but without the degrading sky fog, two shorter exposures stacked atop each other have a higher combined contrast than a longer, single sky-fogged exposure.

Exposing the initial negatives in the Schmidt camera is actually the easy, relaxing part of the astrophotographic process that Ware employs. The time-consuming work really begins in the darkroom where he estimates it takes about six hours and twenty dollars worth of copying materials to go through the steps that produce a final enhanced high contrast printing internegative. But once these steps are complete, the image can easily be printed again and again from the final internegative. Jason uses all-Kodak darkroom materials, finishing the process by printing on Ultra color enlarging paper.

Through the use of fine-grained large-format film, Ware can obtain the high-resolution wide-field celestial views he desires. Jason explains that digitally enhancing the contrast of a single negative with his Photoshop computer program enhances grain, while stacking two negatives in the enlarger tends to cancel grain. He admits that digital enhancement techniques can achieve a similar level of detail with perhaps better contrast and saturation than chemical darkroom techniques, but the digital requirements for medium format have mostly deterred him from using electronic techniques. Scanning, processing, and outputting detailed medium-format images require an enormous amount of computer memory and cost.

By judiciously shopping the used equipment market, Ware has assembled an advanced professional-quality color darkroom at a very modest expense. His secret is patience in waiting for the bargains to appear instead of buying equipment at full retail price. He thus enjoys the use of items such as an automated Jobo film processor and color negative densitometer that are not normally found in darkrooms.

Today, film astrophotography is almost exclusively the domain of the amateur astronomer since the professional astronomer relies mainly on electronic data gathering. In fact, the best amateurs produce better celestial images than the professionals, given equal equipment. The exceptional images produced by astrophotographers such as Jason Ware prove that, in spite of the declarations of CCD aficionados, film is not dead in astronomy. ▪

Above: The rich star clouds of Scorpius surround star clusters M7 (lower left) and M6 (upper right). The image was made with a 12-inch Schmidt camera and a composite of two 7-minute exposures.

Robert Reeves, a long-standing contributor to Astronomy, *is an accomplished sky photographer living in San Antonio.*

Less is More

You can enjoy astronomy on the cheap.

by Bob Berman

Many people who love astronomy also enjoy gadgets. For them, it can be a tough call which gives more pleasure — the pursuit of a new accessory or the sight of the Orion Nebula. The popularity of meetings such as Stellafane in Vermont with its collection of innovative equipment and the number of advertisements in this and other magazines attest to this wondrous age in which helpful devices bring a new level of effectiveness to amateur astronomy.

I've never been immune to the bewitching charm of celestial instrumentation. Though I began at age 12, like so many others, with a simple 2.4-inch refractor from which joy sprang forth disproportionately to its size, I later built a private observatory on a rural site in upstate New York. Gazing adoringly at the telescope's electric cables and dual axis drives, I'd spend as much time admiring it as looking through it; for me it was far more enrapturing than anything in the Louvre.

When telescope builder John Dobson visited my observatory a decade ago, he was not so impressed. Dobson lives happily in poverty. It is simplicity that he admires, a vestige of his years as a monk in an Eastern order. And it was he who made it okay, even fashionable, to own a telescope made of cardboard. He always laughed at the pretentiousness of the term coined by others: "Dobsonian Mount." His design was essentially a "lazy Susan" (a rotating table tray) that merely swiveled up/down and right/left. Suddenly it was respectable to love the stars and yet belong in the raccoon tax bracket.

And isn't this what astronomy was about for millennia? How much fancy-schmancy equipment did the ancient Arab desert-dwellers have, who named most of the stars in the first place?

The point here is not that one can merely *get by* on a low budget, but that one can also have the *full* complement of fun. It is possible to experience the entire educational and wonder-filled joy of astronomy without spending a fortune. Now, while decades have elapsed since my destitute college years when I'd sometimes search chair cushions for loose change in order to buy myself a box of spaghetti, I know from 35 years of lecturing, observatory directorship, and personal experience which inexpensive equipment yields maximum pleasure and how to get the most bang for the buck.

The Free Lunch

Let's start at the bottom, at the cosmic flat-broke level. First category: the Free Lunch. Who says there's no such thing? The library will gladly lend you this magazine and books with star charts, and the heavens emerge gratis each clear night. It seems too obvious to say, but how many of today's beginners first take the time to learn the stars and constellations, a pursuit that doesn't cost a cent? If you want to start from scratch and learn scuba diving or tennis, there's no way

Robin Zingone

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you can gain basic proficiency without coughing up significant dollars. But astronomy is a different story.

Yet, there are thousands of amateur astronomers who don't know the sky at all, who buy expensive equipment only to find themselves at a loss as to what to do next. So before the ancient art of knowing the heavens vanishes as completely as 5-inch floppies, learn the sky.

I believe there is no pleasure in science greater than lying under the heavens away from city lights (preferably in winter from a hot tub or on a blanket in a summer meadow) and being enraptured by the lunatic chaos of the Milky Way. Psst — here's a secret for you beginners: No view through any telescope is better than this! (Different, yes, but not better.)

But when you *do* want to use a telescope, you don't have to invest in one if you're short of funds or an allowance-poor youngster. Most astronomy clubs have loaners. They'll *give* you one to use! Ah ha, you say, but you usually pay some modest membership fee. Well, yes, usually. But you could tell the club president or treasurer that you love astronomy but you're broke due to circumstances beyond your control. As likely as not they'll waive your fee. They'll probably also loan books, magazines, and videotapes.

I've never yet visited a club that didn't have at least some members who exuded enthusiasm for helping beginners; they know that a passion shared is almost always doubled or tripled. Talk to some of these gregarious star-people and you'll be able to choose your company; several will invite you over to use their equipment. Clubs *love* taking newbies under their wings. Most also hold star-party sessions in remote, unpolluted sites, and you can easily get a ride with one of the members if you don't own a car. The nice thing about these is that you automatically get to try out many telescopes. Whenever the time comes that you're financially able to purchase a scope, you'll have a much more educated taste for the pros and cons of various instruments.

Going further, many of the observatories associated with schools and colleges hold regular or periodic public viewing nights. By lingering late, you can probably get them to point the thing anywhere you want and get great hands-on vistas through very expensive and quality equipment.

So far your total astronomy expenditure has been somewhere between negligible and nothing. Again, think of it: If you wanted to pursue horseback riding, say, or stamp collecting, there's *no way* you can coast. Here you can learn everything you ever care to without needing to rob a bank.

Whether observing is done with or without equipment, the issue eventually shifts from what to where, meaning the viewing of special celestial events. Here, too, the cost is usually zero (for meteor showers, lunar eclipses, occultations, and conjunctions) because, as sure as Jehovah's Witnesses, they come to you. It's always fascinating to envision the sheer enormity of the geometry involved when a distant star, an asteroid, and your local county form a straight line across the cosmos. With such an occultation, it's as if that asteroid's "shadow" sweeps over your backyard. And it will, too, if you have the patience to check the year's occultations ahead of time and note which ones will occur in your neck of the cosmic woods. Just circle the calendar and hope for clear weather. Economics play no role whatsoever, except in expensive-to-get-to total solar eclipses.

But I know all this makes you fidgety. As normal well-adjusted people who share to varying degrees the society's materialistic mind-set, it's psychologically hard to be a freeloader. One of life's perks is to scout out and buy things, even when they only marginally enhance our pastime. But some accessories are truly desirable. And so we move to the next level:

$1 to $10

This is a good category because it includes inexpensive birthday presents, such as those glow-in-the-dark stars that stick on the wall or ceiling. These stars can painlessly teach constellations to kids as they drowsily gaze around their room at night. Of course this only works if the stars are put up accurately to match real patterns, which has probably only been accomplished in five children's rooms in the entire United

With just the naked eye and a dark observing site, you can enjoy the Milky Way. To see this level of detail, however, optical aid is required.

Mark Schroeder

States. One quick and precise, if more expensive, method of doing this is by getting ahold of constellation stencils and phosphorescent paint (don't bother asking for them at your local convenience store).

A very helpful, inexpensive accessory is a planisphere, those cardboard or plastic disks you turn to match up the date and time of night that then shows how the sky will look. Even now, after teaching planetarium directors and others for decades, I still occasionally use one when I want to know *exactly* what will be rising at a given time on a particular date. So simple and yet so indispensable.

If you already own a telescope, a good low-cost item is a pirate patch! We all know how much better it is to keep both eyes open at the eyepiece, and this helps black out the view for the unused eye. That it makes you look sexy and roguish doesn't hurt either.

Another important accessory in this price range is a red flashlight — to protect night vision while reading the star charts in this magazine or any celestial atlas. Simply gluing red cellophane to a regular flashlight's front lens or giving it a quick coat of nail polish does the trick.

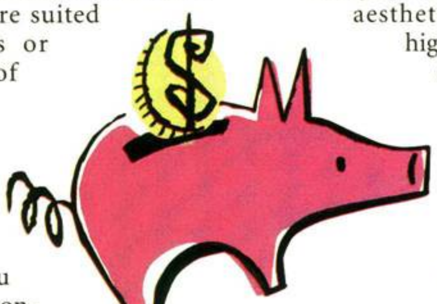
Tim Barnwell

For viewing star clusters such as the Beehive (M44), cheap binoculars are better than the giant Keck Telescope.

$10 to $50

Now a vast realm opens. Here, for the cost of a Hollywood lunch, you can see what no human glimpsed in the heavens until a few generations ago. We're talking binoculars. One of the most undervalued tools on the amateur astronomer's shelf, the unbeatable talent of binoculars to deliver a bright image, wide field, and stereoscopic view makes it a better choice for some objects than, say, the Keck Telescopes.

Too many people think of binoculars as a poor person's instrument, an inferior device more suited for bird-watchers or voyeurs. It's part of the "highpoweritis" disease that temporarily afflicts beginners. In truth, for many star clusters such as the Pleiades, if you had a choice of personally using the Hubble Space Telescope or a $40 pair of binoculars, you'd be wiser to select the latter.



For celestial targets such as these that occupy a full degree or more of the sky, including the star swarm surrounding Orion's belt, the summer Milky Way, or even arguably the Andromeda Galaxy, most telescopes' minimum magnification is simply too high for a satisfactory view. All that you see are a few stars or a diffuse blur; its true nature is lost. For many open clusters and some nebulae, you need not only a wide enough field to take in the entire object, but also enough encircling space to let its nature be aesthetically obvious. Too high a power, too small a field, and its glory utterly vanishes. Here, binoculars are no mere low-budget substitute; they're the first choice, the best, the optimum.

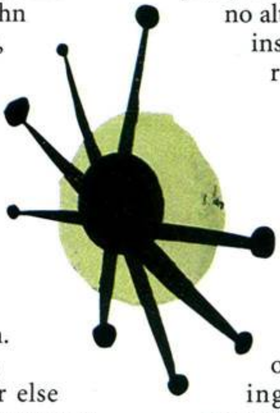
Now, under $50 may seem pretty minimal for binoculars, and it's true that I'd personally spend closer to $150 or $200 if given the choice. However, the jump from *no* binoculars (naked-eye view) to an inexpensive, discount department-store pair of 7x35 binoculars is dramatic. The leap from that instrument to a $200 pair is much less so. Just make sure that the objective lenses (the second number in the "7x35" business) are at least 35mm, since lenses with diameters much less than that don't gather enough light to be optimal for night work. Also avoid "zoom" binoculars and stick with a pair yielding 7 to 10 power (the first number). Check out the binoculars while you're in the store to make sure that the whole field is sharp almost to the edges, that there's no excessive orange or purple color fringing at the borders of high contrast interfaces (moon against night sky, or white store sign against dark background), and that the contrast is stark and pleasing rather than milky and washed out. You'll be surprised at how good the optics can be in a pair found in this low price range.

Here are some other under-$50 treats: a set of celestial slides of the latest Hubble or major-telescope images, a year's subscription to this magazine (or another fine science magazine), a good star chart such as *Norton's* or *Sky Atlas 2000*, an astronomy computer program, a good astronomy book (see this magazine's *Explore the Universe 2000* issue for recommendations), and colored screw-on filters if you own a telescope. All of these will deliver long-term pleasure far beyond the meager price. Check the advertisements in this issue — the possibilities are vast. By comparison, how many quality-comparable low cost presents are available to a friend whose hobby is, say, antique cars?

More than $50

When people arrive at my observatory, the bolder visitors (usually children) sometimes ask the cost of the main telescope and always seem amazed at the answer. A large, impressive looking instrument appears costly indeed, but my own fully-loaded, dual axis-driven, 12.5-inch f/6 only set me back about $4,000; the casual visitor imagines that it cost 10 times more. No question: Acquiring a piece of the cosmos is not a high-budget item, almost always less than the price of a new car, and it takes you trillions of miles farther than a tank of gas.

But the thrust of this article is not what a bargain it is to spend thousands on equipment that is worth every cent, but how to get by on the cheap. And here's where we get back to John Dobson. His idea was that, given a limited budget, you should put all your marbles into the optics and skimp everywhere else. That means a cardboard tube, no clock drive, no rotating tube on smooth metal bearings, no computer guidance. Also, no fancy catadioptric system or even refractor-type optical path. It means a Newtonian reflector.



You buy it prepackaged or else purchase the largest mirror you can afford and the bare necessities, which include a decent 7x50 or 8x50 finderscope and at least one good eyepiece, and wham — you've got a better view than anybody ever had until a scant two centuries ago. These days, what you spend depends on how large a mirror you covet. You can still pull the whole thing off for an amazing $500 or so for a ready-to-use 8-inch reflector, or $650 for a 10 inch. You might even find a lower price at a flea market.

It doesn't cost you a penny to see sky events such as this beautiful conjunction of Venus and Jupiter on February 21, 1999.

Mark Oldfield

Actually, if you're on a budget, you don't have much choice as to where you put your cosmic dollars. There's no alternative: You cannot opt instead to go the opposite route, to have small-diameter optics but an exquisitely fine drive system, like the fabled 3.5-inch Questar Maksutov-type telescopes, because that already is pricey. The *only* way to keep the price down is to "cheap out" on the tube, mounting, drive system, and accoutrements. Indeed, you can pay $850 for the simplest 12.5-inch telescope, or $25,000 for an observatory quality instrument with an identical aperture. Both will brighten equally, both are equally "powerful." But don't *ever* let yourself visit and taste the silky electronic movements, exquisite optical quality, and impressive accessories of the costly instrument because its poorer cousin will suddenly seem as desirable as pond scum.

Still, the low-cost telescope will undeniably "get you there," all the way to far-flung galaxies. Like the old Volkswagen Beetles, they work just fine if you don't mind roughing it a bit, such as sometimes contorting your body into positions that would make your chiropractor wince when using an equatorial instrument with a non-rotating tube. Do be aware that once you cross the line and buy a telescope you generally get what you pay for, but remember not to accept the popular perception that a love of astronomy is synonymous with the need to own a telescope. You do *not* need a telescope to enjoy the starry heavens.

So in nearly all aspects, the cosmos cooperates with the cost-cutter. We whom destiny has endowed with a passion for astronomy are lucky indeed that something as vast as the universe demands accessories that are often so down-to-earth. ▣

Bob Berman is author of the new book Cosmic Adventure *(published by William Morrow and Co.). He wrote "The Art of Skyspeak" in last month's issue of* Astronomy.

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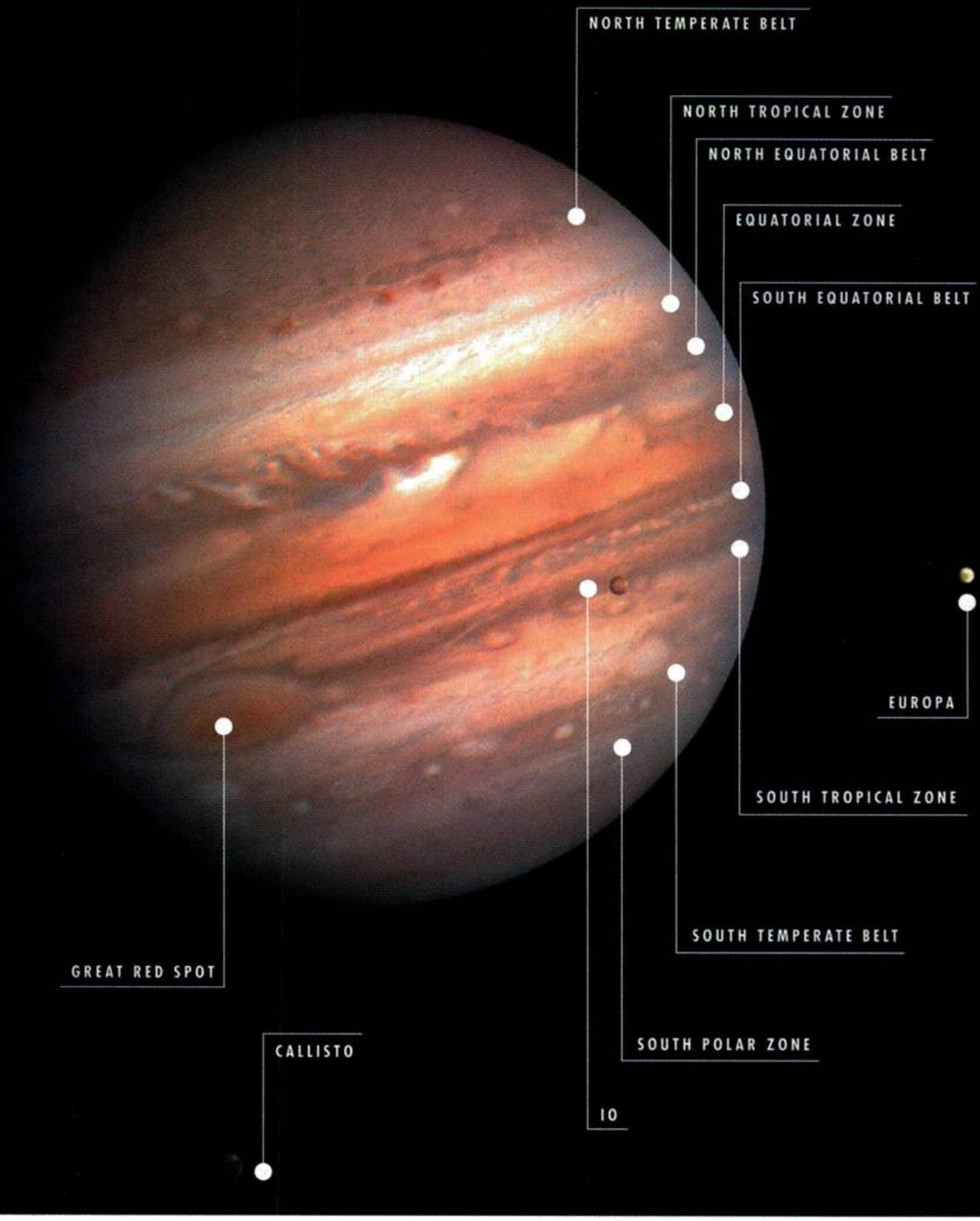
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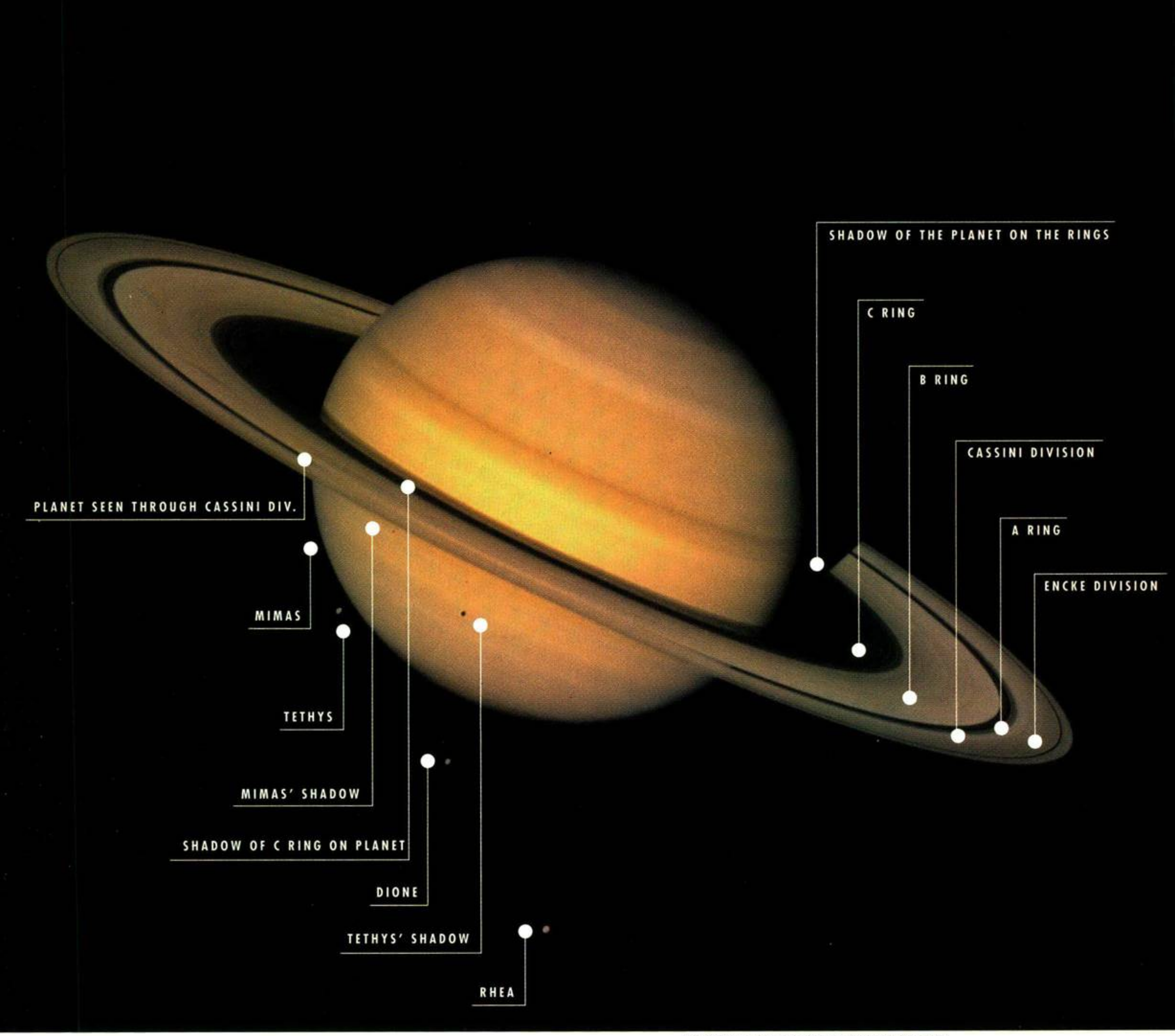
Falling for
Jupiter and Saturn

Rocky rings, raging storms, and a plethora of satellites greet this autumn's opposition viewers. **by Phil Harrington**


SHADOW OF THE PLANET ON THE RINGS
C RING
B RING
CASSINI DIVISION
A RING
ENCKE DIVISION
PLANET SEEN THROUGH CASSINI DIV.
MIMAS
TETHYS
MIMAS' SHADOW
SHADOW OF C RING ON PLANET
DIONE
TETHYS' SHADOW
RHEA

U.S. Geological Survey, NASA, and Astronomy: Terri Field

Few pursuits in backyard astronomy are as universally appealing as observing our planetary neighbors. For those new to the hobby, planet-watching is a wondrous experience. The challenge doesn't diminish as you become more familiar with the sky; indeed, it is just beginning. Many seasoned amateurs, not content with simply looking at the planets, study them intently and make intricate drawings depicting subtle details. Planets also have a great appeal to astrophotographers. Their finest results often can compete with the most professional, ground-based efforts.

Best of all, this can be done from almost anywhere on Earth. Unlike some aspects of amateur astronomy that demand dark skies, planetary viewing permits visiting other worlds from the country, the suburbs, or even from a city. In fact, besides the moon, the planets are often the only celestial objects visible from the middle of a large city.

This autumn, Jupiter and Saturn come into opposition, treating stargazers to bigger and brighter views of our planetary neighborhood's most influential citizens. Opposition is the point in a planet's orbit when it lies directly opposite the sun in our sky and its distance away is at a minimum. These are the best times for observing the outer planets, and the two most-giant planets offer unparalleled views in just about any telescope.

The first of the two planets to reach opposition will be Jupiter, on Saturday, October 23. Some oppositions are better than others. On comparatively rare occasions, Jupiter will reach opposition at or near its closest point to the sun, perihelion. As luck would have it, Jupiter passed perihelion on May 20. As a result, the jovian disk, appearing in the constellation Pisces, will measure 49.7" across — close to its maximum possible size.

Jupiter's immense bulk makes it the king of planets in our solar system. Perhaps the first, most obvious detail you'll notice when viewing Jupiter in a scope is that it's not round. Gigantic Jupiter takes less than ten hours to rotate once, so the planet gets squeezed by the breakneck momentum, flattening it at the poles and causing it to bulge at the equator. Jupiter spans 88,700 miles (142,980 kilometers) in diameter at its equator and is 7% smaller than that from pole to pole.

The most prominent features of Jupiter's clouds are the North and South Equatorial Belts, two parallel dark-brown belts bordering the white, central Equatorial Zone. All three features are visible through telescopes as small as 2 inches in aperture, while 8-inch and larger instruments may further reveal that the South Equatorial Belt is bisected by a pencil-thin bright zone.

Lying on the southern edge of the South Equatorial Belt is Jupiter's famous Great Red Spot. In 1665, Giovanni Domenico Cassini and Robert Hooke independently discovered the great swirling storm. And a great spot it is, for it measures some 19,000 miles (30,000 km) long by 9,000 miles (14,000 km) wide (by contrast, Earth is a paltry 4,000 miles in diameter). But while it measures up in greatness, the Red Spot is rarely red. Instead, it varies between an anemic orange, beige, salmon, and at times, even pale white.

Finding the Red Spot requires a slow and methodical search; a quick glance may not distinguish it from its surroundings. Aperture can be used to your advantage, as the greater light-gathering ability of larger instruments will help accentuate its weak coloration. My 8-inch reflector rarely shows the spot as more than a pale-orange blemish, while an 18-inch reflector reveals a more prominent salmon color. Of course, the Red Spot also might not be visible simply because it is occasionally on the farside of the planet. If it is nowhere to be found, remember that Jupiter revolves once every 10 hours, so come back a few hours later and try again.

Larger instruments and higher magnifications will also reveal a multitude of other less-prominent belts and zones across Jupiter. These include the North and South Temperate Belts and Zones, North and South Tropical Belts and Zones, and North and South Polar Zones. Color filters help highlight some of these subtle details. Try using a yellow-green (Wratten #11) or orange (#21) filter to pick out tenuous features in the darker belts. A green (#56 or #58) or blue (#38A or #80A) filter helps accentuate the Red Spot's visibility.

Jack Newton

Jack Newton

Jack Newton

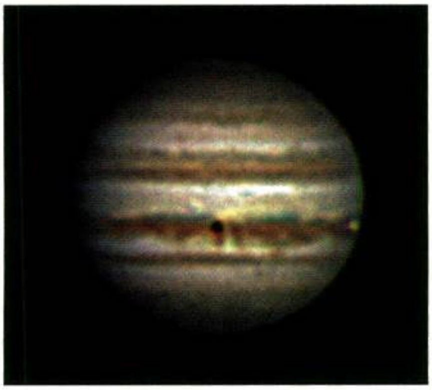
Gazing at Jupiter, we are looking at the planet's top layer of an incredibly deep atmosphere. Studies show its clouds are composed of about 90% hydrogen and 10% helium, with traces of methane, water, and ammonia. What lies beneath those clouds is uncertain, but current research suggests Jupiter has a solid core of rock and ice ten to fifteen times the mass of Earth, encased in liquefied metallic hydrogen.

One glance through nearly any telescope will show that Jupiter's atmosphere puts on a spectacular show of alternating dark and light bands. Heat convection from deep within Jupiter's interior, created by gravitational compression, is responsible for the complex banding visible in the cloud tops. The bright zones in Jupiter's atmosphere are composed of clouds of ammonia ice crystals, while the dark belts are regions of ammonium hydrosulfide and other compounds. Swirling eddies can be spotted in the maelstrom that marks where the belts and zones thrash together, testifying to the turbulent nature of Jupiter's atmosphere.

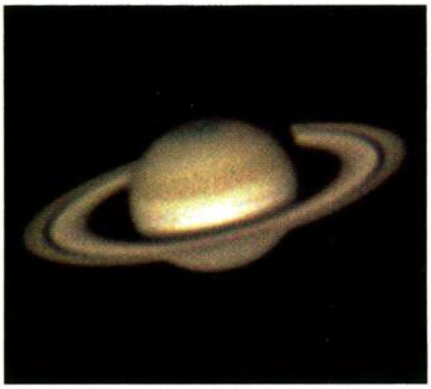
Besides Jupiter itself, the dance of its satellites provides an enticing show. Only the brightest four moons of Jupiter are visible in binoculars and amateur telescopes, although there are 16 total. In 1610, Galileo became the first person to record their presence, and so today, we call them collectively the Galilean satellites, with each named for a mythological lover of the Roman god Jupiter. All four Galilean moons orbit in the plane of Jupiter's equator, restricting their positions to directly east or west (left or right) of Jupiter's bulge. Innermost of the four is Io, a pockmarked, volcanically active moon 2,300 miles (3,600 km) in diameter, which takes just 1 day and 18 hours to complete an orbit. Next out, icy Europa carries its 2,000 mile (3,100 km) diameter around Jupiter in 3 days and 13 hours. Ganymede, the largest satellite in the solar system with a diameter of 3,200 miles (5,200 km), takes just under 7 days and 4 hours to orbit, while Callisto, the outermost Galilean satellite, takes 16 days and 16 hours. Callisto is the second largest Galilean satellite with a diameter of 3,000 miles (4,800 km) but is the faintest of the four due to its low albedo. Visit page 65 for a chart on the nightly positions of the four Galilean moons. Occasionally you may catch one make a transit — when a moon passes in front of Jupiter. Watch the satellite's circular shadow advance across the cloud tops, preceding the appearance of the body itself.

As tantalizing as Jupiter is, it faces stiff competition as another outer planet rises into the sky. Many consider Saturn the most beautiful sight in the heavens. It's always a crowd pleaser at star parties and public viewing sessions and is probably responsible for luring more people into astronomy than any other celestial object. And now, Saturn rejoins our night sky, reaching opposition in Aries on November 6.

Without a doubt, the single biggest attraction of Saturn is its wonderful ring system. Galileo saw there was something odd about Saturn's telescopic appearance when he viewed it in 1610, but his telescopes were so poor that he was unable to determine what he was seeing. He thought the rings were "handles" or large moons on either side of the planet. His notes recall "I have observed [Saturn] to be tripled-bodied. This is to say that to my very great amazement Saturn was seen to me to be not a single star, but three together, which almost touch each other." His early drawings of Saturn show a silhouette almost resembling a droopy-eared Mickey Mouse. It was not until 1659 that Dutch astronomer Christiaan Huygens solved the mystery. He noted that Saturn is surrounded by "a thin, flat ring, nowhere touching, and inclined to the ecliptic." Indeed, Saturn possesses an intricate system of rings, each composed of billions of chunks of rock and ice ranging in size from specks to icebergs miles across.



Don Parker



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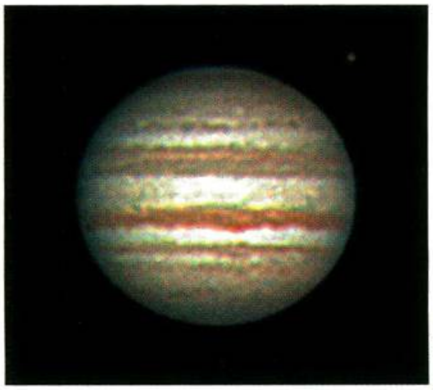

David Hanon

First-time observers of Saturn don't realize just how easy it is to see the rings. All you need is a 2-inch telescope magnifying 30 times (30x). Unfortunately, many believe that high magnifications will produce a better view. The best views of the rings generally occur between 100x and 200x, depending on telescopic aperture, quality, and seeing conditions.

Careful scrutiny through a 3-inch or larger telescope will show that Saturn's rings are divided into zones. The most obvious division in the rings is a dark band called the Cassini Division, named after the Italian astronomer Cassini. Discovered in 1675 (a decade after he first observed Jupiter's Red Spot), the Cassini Division separates the fainter, outer "A" ring from the brighter, inner "B" ring. Once thought to be an empty gap, the Cassini Division was revealed by photographs from the Voyager spacecraft to contain bits of opaque material. A third major ring, the "C," or crepe, ring, lies just inside the B ring, although even large telescopes have a difficult time making out its dim presence. Try looking for its silhouette against the bright planetary disk. Another division, called the Encke Division, slices through the A ring but is very difficult to spot even through the largest backyard instruments.

After appearing edge on and effectively disappearing from view in February 1996, Saturn's rings now show themselves in all their glory. This fall and winter, Saturn's rings can be seen tilted at approximately a 20° angle, exposing the southern face to Earth. Their angular tilt will continue to increase slowly, widening to a maximum of 27° in 2002.

By definition, when Saturn is at opposition, it appears fully illuminated as seen from our vantage point on Earth and so appears rather flat, like the full moon. Viewing the planet for several months on either side of opposition, however, will reveal the shadow of the planet cast onto the rings, creating a spectacular 3-D effect. Begin your observations tonight and pay close attention to the shadow's appearance on the rings. As time goes by, the shadow will shrink, disappear around opposition, then slowly reappear from the opposite edge of Saturn in the days and weeks that follow.

The spectacular atmospheric phenomena seen on Jupiter are nowhere to be found on Saturn, despite its similar composition. Due to Saturn's greater distance from the sun, solar radiation may not produce the complex chemical reactions responsible for Jupiter's colorful show. The only evidence of banding visible on Saturn through most backyard telescopes will be the subtle differences in shading between the equatorial region and darker polar regions.

Saturn is orbited by 18 satellites, tied for the most moons with Uranus. Among these satellites is Titan, second largest moon in the solar system and the only one with a significant atmosphere. Titan takes a little less than 16 days to complete one orbit of Saturn and is bright enough to be seen with a pair of steadily held 7x binoculars when it's farthest from the planet's disk. As many as six other satellites are bright enough to be seen through a high-quality 6-inch telescope, although often some are too close to the planet to be spotted.

Enjoy the views of our planetary family's most striking members this fall. They promise to put on a terrific show. ■

Phil Harrington's latest article for Astronomy *was "Red Planet at Night, Observer's Delight," April 1999.*

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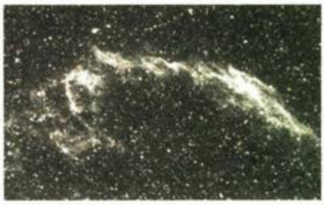

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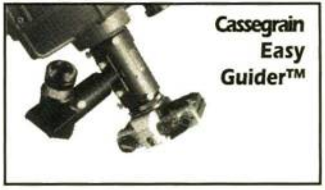

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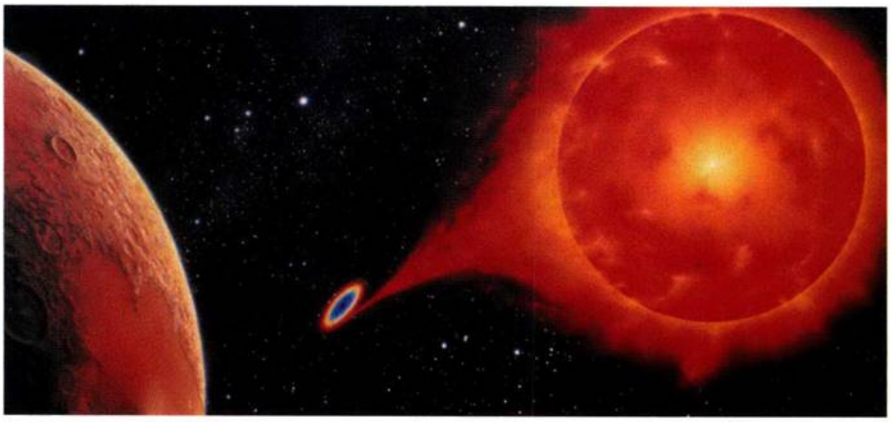
Brown Dwarfs, Gravity, Asteroids



A stellar-mass black hole draws material away from its ruddy companion. Kim Poor

Q: When stars become black holes, is there a certain distance at which their gravity will have an effect on other objects? If so, how close do those objects have to be?

— Kristi Kendell, Layton, Utah

A: The gravity you feel from an object depends on only two things: the mass of the object and the distance you are from it. Imagine the sun has turned into a black hole. The mass of the sun stays the same and our distance to it stays the same, so on Earth we would feel the same gravity. Isaac Newton once showed that if you are far away from an object, it is mathematically okay to pretend as if all the mass of that object is concentrated into a single point. So at our distance to the sun, it makes no difference if the sun is as big as it is or if it's collapsing into the space of a black hole.

The difference comes when you get close. At some point, you get to a place where you are the same distance from the black hole as the old radius of the sun, and Newton's approximation breaks down. You can't get any closer to the sun than right on it. But the black hole is smaller, so you can keep getting closer, and the closer you get, the stronger the gravity. Eventually the gravity becomes so strong that the escape velocity becomes the speed of light, and you're doomed. Nothing can escape such fierce gravity at that distance from the hole.

So the lesson here is keep your distance and you'll be fine. — *Phil Plait*

Q: Is Jupiter in any way like a brown dwarf?

— Rita Kaufman, Port Charlotte, Florida

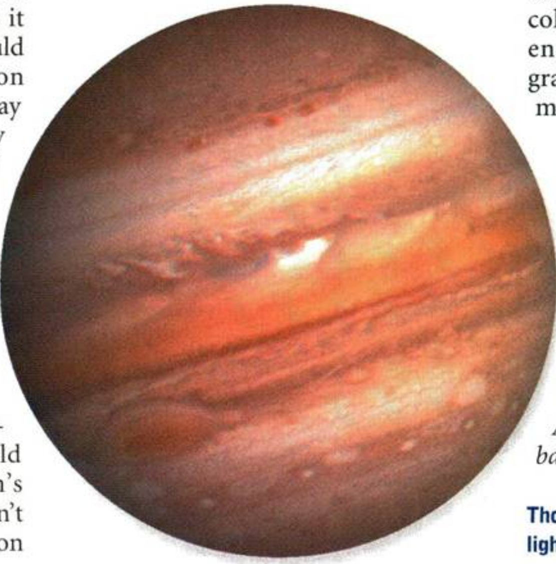
A: A brown dwarf is a low-mass star that, because of its low mass, cannot fuse hydrogen in its core like a regular star. As a result, it becomes a big, gaseous object that radiates little visible light.

In some ways, these objects do resemble Jupiter. They are typically Jupiter-sized, although much more dense than the planet. The most massive brown dwarf weighs about 80 Jupiters, or 0.08 times the sun. (Any bigger than that and the pressure on the core would begin the fusion process, resulting in a star.) Yet the apparent diameter of these weighty stars is no bigger than Jupiter's.

Brown dwarfs also seem to have an atmosphere — something many stars lack because their hot temperatures quickly burn up fragile molecules. Gliese 229B, a brown dwarf located 19 light-years from Earth, has large amounts of methane and water vapor in its upper atmosphere, giving it a composition similar to Jupiter and Saturn's moon Titan.

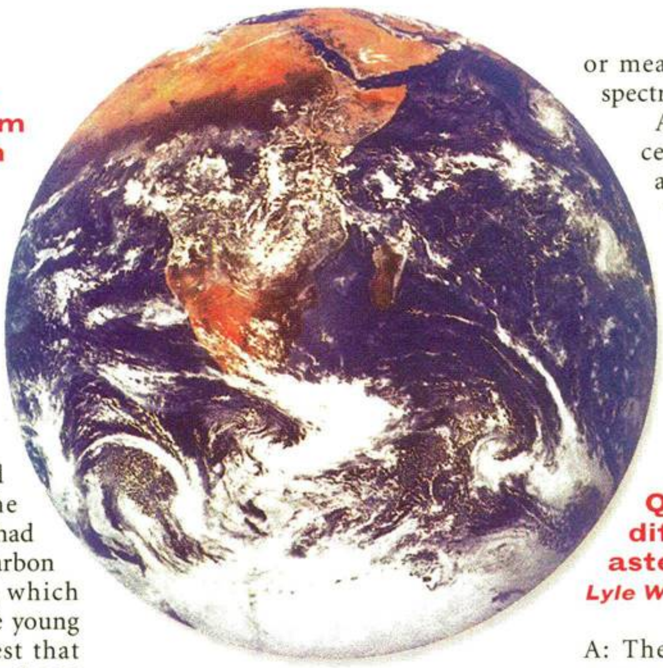
But brown dwarfs and Jupiters form differently, which makes the two dissimilar in a fundamental way. Stars develop from the gravitational collapse of a cloud of gas and dust. If enough mass exists in the fragmented cloud to put pressure on the core and start fusion, a star will form. In the case of a brown dwarf, the mass is high enough to collapse the cloud, but not high enough to produce nuclear fusion in the core. A planet, on the other hand, forms from particles in the cloud colliding and sticking together. Once enough mass accretes this way, the gravity of the young planet will attract more particles.

Differentiating a brown dwarf from a planet remains a challenge to astronomers. If they find an object 10 times Jupiter's mass, they cannot immediately label it without knowing how it formed. In that case, who cares what you call it? As Shakespeare said, a rose by any other name would smell as sweet. — *Phil Plait, The Bad Astronomy Web Page: http://www.badastronomy.com*



Though sporting a hefty girth, Jupiter is a lightweight compared to brown dwarfs. NASA

Q: How did Earth remain warm enough to keep its oceans from freezing when the sun was fainter than it is today? Could the same physics that caused the moon to spiral away from Earth put our planet closer to the sun? — *David Fuller, Forest Park, IL*



Earth's gases helped water stay liquid. NASA

A: One mechanism that helped keep Earth warmer was the greenhouse effect. Early Earth had an abundant greenhouse gas, carbon dioxide, in its atmsophere, which absorbed heat given off by the young sun. In fact, estimates suggest that Earth's atmosphere contained 100 times more carbon dioxide than all the gas in the air today. For a modern-day comparison, look at Venus. It has roughly the same amount of carbon dioxide in its air and stores a tremendous amount of heat as a result. So, while the sun may have emitted less energy, more of that energy was stored in the air to keep the planet warm than occurs today. In this way, the oceans did not freeze.

Yes, the moon was originally much closer to Earth. We are not sure exactly how close, but we guess it was probably about 10 times closer. The closest it could have initially been was about 20 times closer, which is near its Roche limit. Inside the Roche limit, Earth's tidal force would have kept the moon's material together as a ring system around Earth.

The moon's orbital period around Earth (its revolution rate) has slowed and continues to slow as it receives energy from Earth and thereby spirals outward. The energy the moon gets from Earth comes from the closer of the two high ocean tides the moon creates here. This tide pulls the moon forward in its orbit, giving it the energy to spiral outward. For every action, of course, there is an equal but opposite reaction.

Conceptually, the same physics that caused the moon to spiral away from Earth could put Earth closer to the sun. However, the gravitational force of Earth on the sun is small. The resulting gas tides Earth creates on the sun are too weak to pull Earth forward in its orbit around the sun, giving Earth energy to spiral outward. So, from a practical point of view, Earth has not moved outward due to this effect. — *Neil Comins, Physics and Astronomy Department, University of Maine*

Q: Does a planet's spin lessen the gravity around its equator due to centrifugal force? Would you be weightless at the center of a star or planet because mass surrounds you in all directions? — *Jeff McConville, Ontario, Canada*

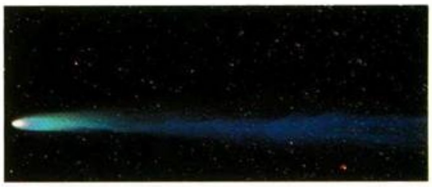
A: To answer the first questions, yes, but for existing planets it is a tiny effect, not noticeable in day-to-day activities. It would be noticeable on a planetary body with a period of spin as short as an hour or an hour and a half (instead of our 24 hours). At that speed, centrifugal force would throw material off at the equator.

This effect gets interesting for asteroids. They have a typical spin period of something like 8 to 10 hours, with a few having periods as short as two hours. As a result, dust could become knocked off the equators easily by external events such as micrometeorite impacts. This would leave the asteroid with bare, rocky equators and dusty poles. The whole question of loose dust on asteorids becomes important from the point of view of landing on an asteroid or measuring its composition with spectra.

As for being weightless at the center of a star or planet, the answer is, technically, yes, you would. However, you have no place to float because the centers of stars typically contain super-dense matter, and planets typically have metallic or rocky centers. — *William Hartmann, Planetary Science Institute*

Q: What is the difference between asteroids and comets? — *Lyle Werner, Valparaiso, Indiana*

A: The major difference between comets and asteroids is what they are made of, which reflects where in the solar nebula they formed. Comets are roughly a 50–50 mixture of ice and small dust grains (with some volatiles such as carbon dioxide, methane, and so forth), and developed at low temperatures beyond the orbit of Neptune. Asteroids consist of rock and formed in the inner solar system. Heavy asteroids have greater mechanical strengths, making their impact more powerful than comets. However, comets more often cross Earth's orbit with higher velocities, and so both make quite impressive impact craters when they strike. — *Geoffrey Blake, California Institute of Technology* ■



Comets and asteroids are closer cousins than astronomers once thought. Ronald E. Royer

CONTACT INFO

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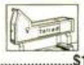

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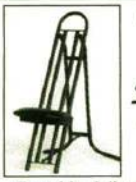

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This new line emphasizes German quality in both the optics and the mechanical tolerances, while being priced well below that of the leading German brands.

Deutsche Optik, P.O. Box 7518, San Diego, CA 92167; phone, (800) 225-9407; fax (619) 287-9869; e-mail, deutoptik@aol.com; website, http://www.deutscheoptik.com. 15x60BGA*: $899 (includes a softcase and tripod adapter),* 8x22*: $199,* 10x25*: $219.*

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The Antennae image features two interacting galaxies caught in the midst of a collision, while the Lagoon Nebula image reveals a glowing cloud of gas and dust powered by the ultraviolet light of newly formed stars deep in its interior.

The Hubble Deep Field South image features NASA's latest venture into the distant universe. Based on observations made last autumn, the image reveals more than 2,000 galaxies, including the faintest and most distant galaxies recorded.

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Astrographics Publishing, 85 Oakside Drive, Smithtown, NY 11787; phone, (888) 8-ASTRO-8; fax (516) 366-5356; e-mail, mail@astrographics.com; website, http://www.astrographics.com. HST posters*: $11.95 each, or with the purchase of three or more, $10 each plus shipping and handling.*

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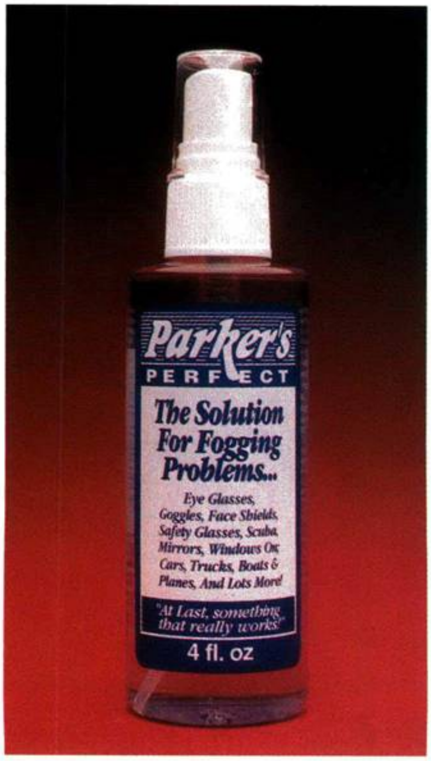
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"*Astronomy* also hits the marketplace I'm looking for," Dan says. "The magazine is written for amateur astronomers, not scientists, who want more hands-on advice. I've had a lot of interest in my products over the past year, and sales have steadily grown. I would have zero business without my ad in *Astronomy*.

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BOOKS

The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory

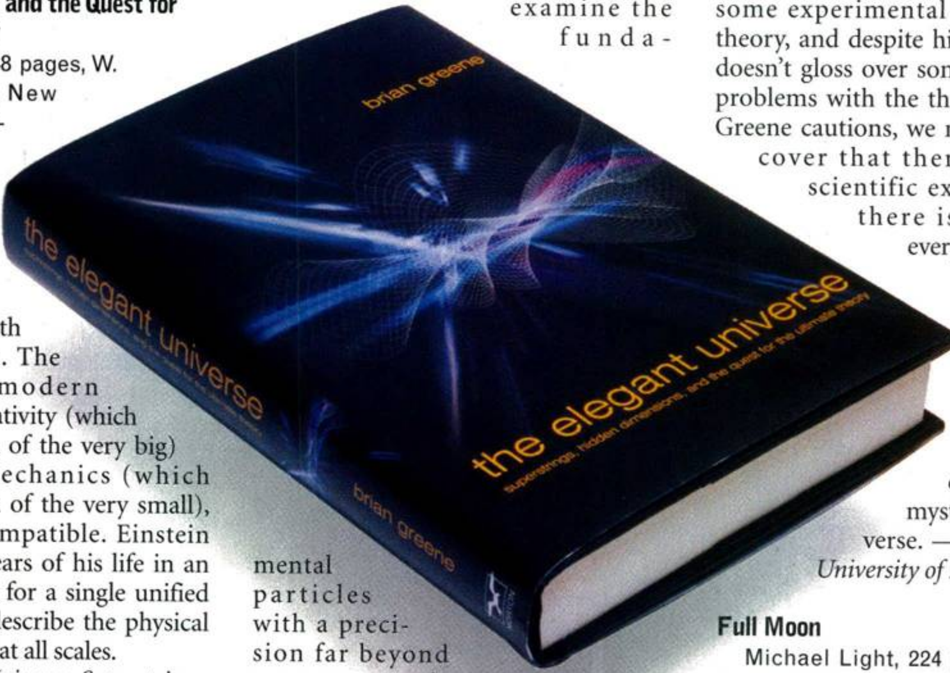
Brian Greene, 448 pages, W. W. Norton & Co., New York, 1999; ISBN 0-393-04688-5; hardcover, $27.95.

▶ For more than half a century, physicists have been faced with a central problem. The two pillars of modern physics, general relativity (which describes the realm of the very big) and quantum mechanics (which describes the realm of the very small), are mutually incompatible. Einstein spent the last 30 years of his life in an unsuccessful search for a single unified theory that could describe the physical laws of the universe at all scales.

In *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory*, Columbia University physicist Brian Greene chronicles the rise, fall, and resurgence of superstring theory (string theory for short) as the best candidate for a "theory of everything." In his 1994 bestseller *Hyperspace*, City College of New York physicist Michio Kaku provided an excellent introduction to string theory. Greene's book covers much of the same territory; however, Greene tells the story from a different perspective and explores many new ideas and recent developments.

In the first chapter, Greene introduces three pivotal conflicts physicists have encountered in the past century. The first, concerning the motion of light, was resolved by special relativity. The second, regarding the propagation of gravitational forces, was resolved by general relativity. String theory seems to offer a resolution to the third conflict — the incompatibility between general relativity and quantum mechanics.

String theory offers an exciting solution to one of the great scientific mysteries of our times: why each of the fundamental particles has the specific properties (mass and force charges) we observe. Is it just by some random choice of nature? According to string theory, if we could examine the fundamental particles with a precision far beyond our current technological ability, we would find that each is composed of a tiny one-dimensional loop, dubbed a string. The observed particle properties are a reflection of the various ways a string can vibrate.



Even more stunning, string theory suggests that the universe has more than three spatial dimensions. In fact, we are told, it has nine: the three familiar dimensions of length, width, and height plus an additional six which are curled up and too small to see. To illustrate this, Greene has us envision a garden hose. Viewed from a distance it looks like a geometric line, one dimensional. As we move in closer, a second curled up dimension appears: the circumference of the hose. We can imagine that each point in our universe is attached to an invisibly tiny six-dimensional sphere. Including time, string theory tells us we live in a 10-dimensional universe!

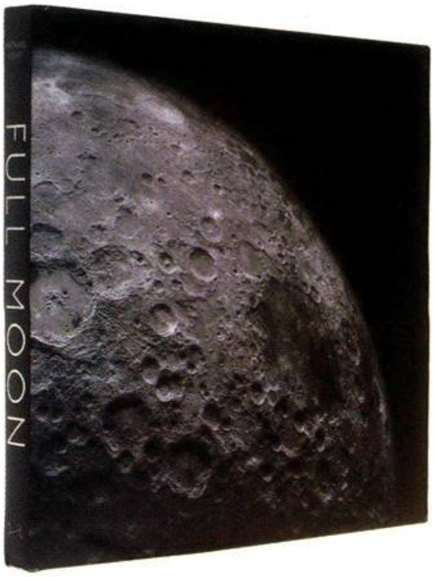
All this has some interesting consequences for black holes and cosmology, which Greene elucidates with depth and clarity. Greene has a rare gift for explaining the most challenging scientific ideas, and everyone can appreciate his refreshingly insightful explanations. The subject matter necessitates a good introduction to special relativity and quantum mechanics.

In his final chapter, Greene offers some experimental tests for string theory, and despite his enthusiasm, he doesn't gloss over some of the current problems with the theory. In the end, Greene cautions, we may one day discover that there is a limit to scientific explanation, that there is no theory of everything. He has no doubt, however, that "there are even grander surprises in store for us" as we continue to delve into the mysteries of the universe. — *Jennifer Birriel, University of Pittsburgh*

Full Moon

Michael Light, 224 pages, Alfred A. Knopf, New York, 1999; ISBN 0-375-40634-4; hardcover, $50.

▶ This large format book contains 72 color and 56 black-and-white photographs from the Apollo program, most of which have not been previously published. The pictures show the moon from orbit, the lunar surface, spacecraft, astronauts, and Earth. The image reproduction is remarkably detailed and sharp, and each image



Check Out Springer Travel Guides to the Moon and Beyond

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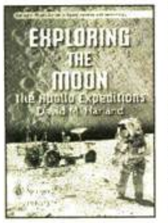
The Apollo Expeditions



"A detailed guide to what the astronauts did during their stays on the lunar surface.... Walk[s] the reader through the prospecting excursions and then incorporate[s] decades of subsequent analysis to put the explorations of dust, rocks, craters, and rilles into geologic context." — SKY & TELESCOPE

Using the actual transcripts of what the astronauts said while carrying out their duties, and numerous photographs taken at each step (and on each drive) of the exploration this book provides a graphic and lively account of what can arguably be described as humanity's greatest feat of exploration.

1999/411 PP., 202 ILLUS./SOFTCOVER/$39.95/ISBN 1-85233-099-6

PRAXIS **SPRINGER-PRAXIS SERIES IN SPACE SCIENCE AND TECHNOLOGY**

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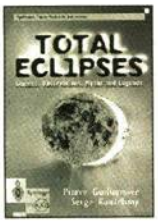

"Gives a wide variety of information on observing eclipses for the novice as well as on the value of eclipses to professionals... any reader can find information at an interesting and appropriate level and can be sure that he is being guided knowledgeably." — NATURE

More than a detailed scientific study of solar and lunar eclipses (at a level appropriate for undergraduates), this new book is also a fascinating survey of the myths and legends associated with eclipses and their observation, throughout history.

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S.F. TONKIN, Hants, UK (Ed.)

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Offers a variety of designs for telescopes, mounts, and drives suitable for the home constructor. The designs range from simple to advanced, but all are within the range of a moderately well-equipped home workshop. Each chapter begins with reasons for undertaking the project, then looks at theoretical consideration before finishing with practical instructions and advice.

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ISBN 1-85233-055-4
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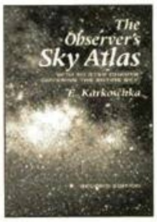
E. KARKOSCHKA, University of Arizona, Tucson

The Observer's Sky Atlas

With 50 Star Charts Covering the Entire Sky
Second Edition



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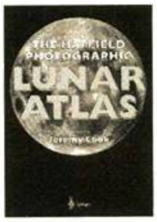
Contains updated star charts, information, and tips for all those who observe the night sky with unaided eyes, with binoculars, or with small telescopes.

1999/136 PP., 61 ILLUS., 50 TABLES/SOFTCOVER/$19.95
ISBN 0-387-98606-5

J. COOK, Camberley, UK (Ed.)

The Hatfield Photographic Lunar Atlas



Long regarded as the finest photographic lunar atlas available, *The Hatfield Photographic Lunar Atlas* is a model of accuracy and clarity. This new version updates some of the maps, names and technical data, but uses Commander Henry Hatfield's original—and unexcelled—photographic plates, taken with a custom-built 12-inch reflector. Superb large-scale photographic plates and full-scale maps accompany the photographs, which provide easy identification of, and navigation through, lunar features.

1999/96 PP., 104 ILLUS./HARDCOVER/$44.95
ISBN 1-85233-018-X

P. MOORE, Selsey, UK, and **A. CHAPMAN**, Oxford, UK

Patrick Moore's Millennium Yearbook

The View from 1001 AD

Celebrate the turn of the wrong millennium with this thoroughly entertaining book that contains articles on King Alfred's "recent" history, reviews of the "new" Star Catalogue by the Arab Al-Sufi, the "latest" edition of Ptolemy's Almagest, and more. Foreshadowing the change to metric units by 1000 years, the book uses arabic numbers instead of Roman - but there is a conversion table if you have trouble with the concept of zero.

1999/APPROX. 100 PP./SOFTCOVER/$24.95 (TENT.)

S. WEBB, Loughborough University, UK

Measuring the Universe

The Cosmological Distance Ladder

Provides a unified treatment of the various techniques used for distance determination. It begins by describing methods to measure distances on Earth, then gradually climbs the 'distance ladder' to enable us to estimate the distance to the farthest known objects, ending with a discussion of particle horizons within an expanding and inflationary universe.

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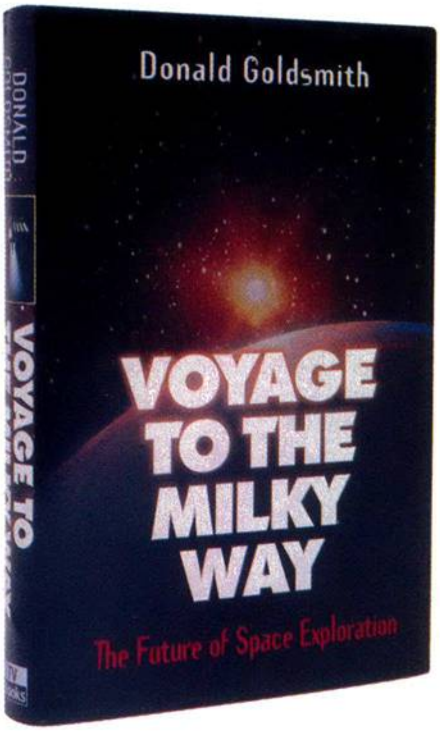
covers at least an entire page. The captions, a short text about the photos, and an essay about Apollo come at the end. It's no contest: This is the most beautiful and spectacular book of moon photographs ever published.

Voyage to the Milky Way: The Future of Space Exploration

Donald Goldsmith, 255 pages, TV Books, New York, 1999; ISBN 1-57500-046-6; hardcover, $27.50.

▶ In this companion volume to the two-hour PBS series *Voyage to the Milky Way*, veteran science writer Donald Goldsmith examines the future of space travel, addressing questions such as lunar colonies, manned voyages to Mars, mining asteroids, cybernetics, and interstellar travel. Goldsmith dispels some of the prevailing myths of space travel, while providing down-to-earth analysis of the technologies that might someday take us to the stars.


Donald Goldsmith
VOYAGE TO THE MILKY WAY
The Future of Space Exploration
DONALD GOLDSMITH
VOYAGE TO THE MILKY WAY
TV Books

The Planets

David McNab and James Younger, 240 pages, Yale University Press, New Haven, Conn., 1999; ISBN 0-300-08044-1; hardcover, $35.

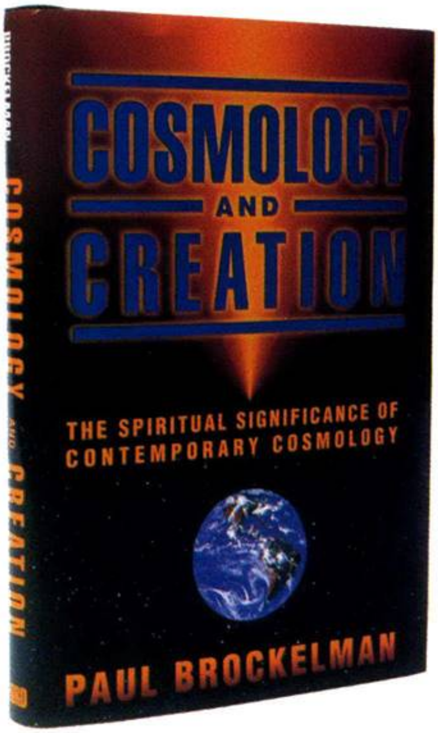
Lavishly illustrated and written in an engaging and accessible style, *The Planets* is sure to please. It begins with the story of Clyde Tombaugh's discovery of Pluto in 1930. Then it quickly moves to the rest of the solar system, covering subjects in a topical manner rather than chronologically. The Planets features both manned and unmanned space exploration, and includes the latest photos from Galileo and Mars Global Surveyor. The authors do a superb job of explaining the formation and evolution of each planet.

Later chapters discuss the sun, life inside and outside the solar system, and extrasolar planets. The book comes with many helpful sidebars and boxes.

Cosmology and Creation: The Spiritual Significance of Contemporary Cosmology

Paul Brockelman, 194 pages, Oxford University Press, New York, 1999; ISBN 0-19-511990-8; hardcover, $23.

▶ University of New Hampshire theologian and philosopher Paul Brockelman offers yet another attempt to bridge the gulf between science and religion. Brockelman argues that big bang cosmology has much in common with creation myths of the past, but he accepts the scientific method and does not refute the Big Bang as an actual event. Brockelman tries to take a scientific creation story a step further, to show how science's view of the universe has the power to move people spiritually. "Science now can be thought of as revelations in which nature is permitted to show itself to human understanding in new ways that deepen and increase our sense of wonder and awe," he writes.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THE SPIRITUAL SIGNIFICANCE OF CONTEMPORARY COSMOLOGY
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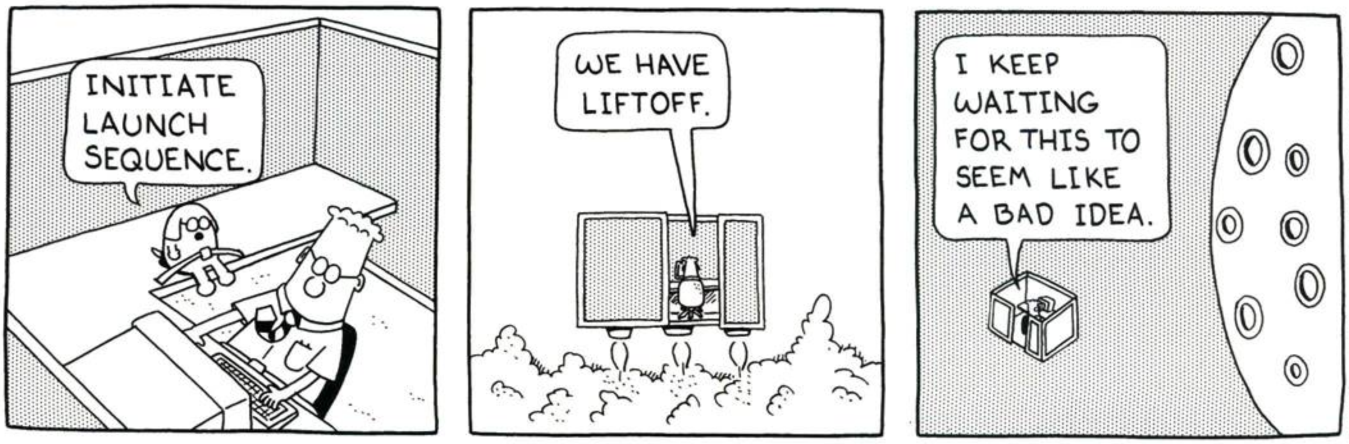
COSMOLOGY AND CREATION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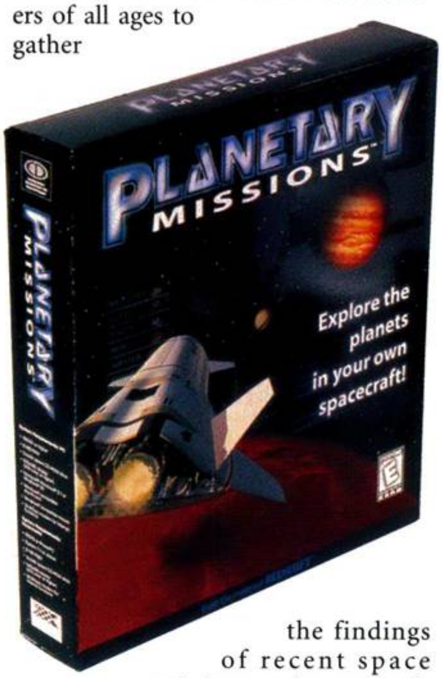

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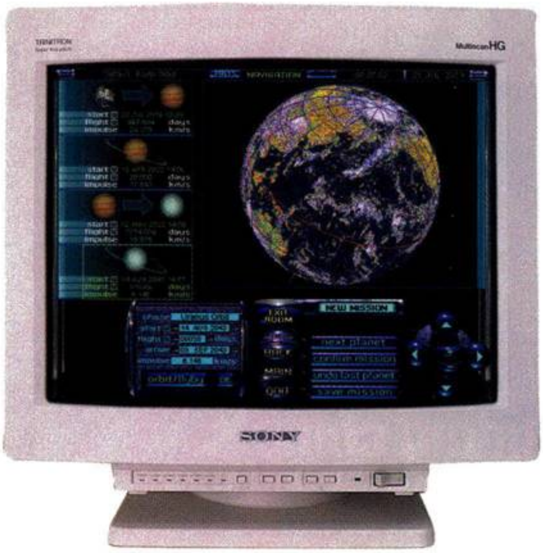

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http://www.webcom.com/shownet/medea/bulfinch/bulfrane.html

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NASA

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Far from the peaceful place it may seem, the universe is fraught with dangers that could destroy life on Earth.

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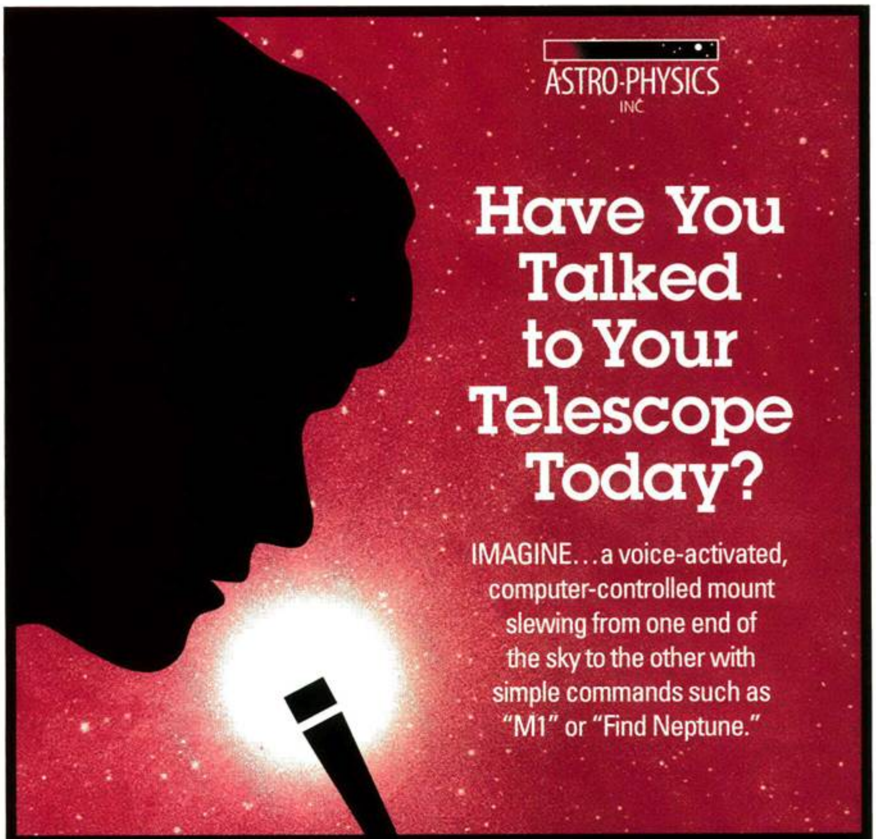
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The Ultima comes with full length adjustable height tripod; heavy duty wedge with deluxe accessory upgrade; setting circles; manual slow motion controls; dust covers; 1.25" star diagonal; 26mm Plössl eyepiece; and a 9 x 50mm finderscope.

The built-in Ultima worm-gear DC drive operates for up to 50 hours on a single 9-volt battery and includes a built-in dual-axis drive corrector that has periodic error correction, four drive speeds, a hand control, and a *free* $170 list price declination motor (normally an option that costs $119^{50}).

The **Ultima 11** and normally optional #2327 dec motor have a combined list price of $5768 and a dealer *cost* of $2884. But your anniversary sale price is only $2499! Less than 20 are still available at this sale price.

You won't believe our price on Celestron's $280 dual-axis drive corrector when you buy a Celestron G8!

Celestron 8" G8
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To celebrate our 20th anniversary, we made a special buy on 200 Celestron G8 8" Schmidt-Cassegrains and dual-axis drive/drive correctors that let's us give you the drive at a *very* special price when you buy the scope.

The German equatorial mount G8 has all the standard Celestron accessories. The battery-operated dual axis drive is Celestron's latest $280 list MDCG5D.

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We'll sell you the *right* telescope.

The right scope might be a TeleVue.

TeleVue TV-85, in stock, **$1995**

Hardly a week goes by that TeleVue doesn't send us a copy of a new warranty card from one of our customers – to let us read the glowing comments about the TeleVue scope they bought from us. While we're pleased to hear we've satisfied another customer, we've come to expect nothing but praise for TeleVue scopes.

TeleVue's short focal length ultra-premium refractors give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power observing (one test report said they used an amazing 89x per inch of aperture on the Ranger, the least expensive TeleVue), all without losing optical quality.

Pronto, **Ranger**, the **TV-85** and **TV-101**, the brass **Renaissance** – all TeleVue refractors are built to the same uncompromisingly high optical and mechanical standards. At the time this was written (7/10), we had every TeleVue scope in stock at ***astronomics***.

All TeleVue eyepieces are in stock

We also stock TeleVue eyepieces, Barlows, and accessories in depth. Whether it's a Plössl, Nagler, Nagler 4, Radian, Panoptic, Paracorr, Powermate, Tele-Pod, Gibraltar, Qwik-Point, Starbeam, or BinoVue – we carry them all. If it's a TeleVue, chances are good we have it in stock.

The right scope might be a Questar.

Questar 3.5" Standard **$3399**

For many people, the thought of a 3.5" scope that *starts* at $3399 is enough to curl their toes. But for those who want the best small telescope made, $3399 is a bargain.

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Want a Questar, the premier portable telescope? We stock them.

Or it might be this 4.5" Bushnell for only $199!

BUSHNELL

Bushnell Voyager 4 **$199**

For most people, Bushnell means binoculars and small "department store special" telescopes. But Bushnell is getting into serious entry-level astronomical observing with their new and reasonably-priced imported tabletop and Dobsonian reflectors.

The **4.5" f/3.5 Voyager**, right, has two 1.25" eyepieces (16x and 100x), a true rack and pinion focuser instead of rubber roller focusing, a carrying strap, a tripod-adaptable altazimuth tabletop cradle mount, and a price that's much, much lower than similar-design factory-direct competitve scopes.

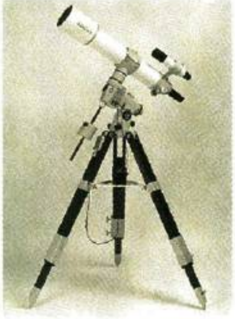
If you want a full-sized Dobsonian scope, a 6" f/8 Bushnell *metal-tube* Dob costs $299 and an 8" f/6 is only $399! Both come with a 6 x 30mm finder and 25mm eyepiece (49x) as standard equipment.

One small step for man. One quantum leap for binocular observing.

"Truly a quantum leap in binocular observing." That's how *Sky & Telescope* reviewed the image-stabilized **Canon 15 x 45mm binoculars**. They also said "astounding . . . supercrisp . . . particularly impressive was how well these binoculars compared to much larger apertures . . . totally blew away what I had seen in the 7 x 50s!" For hand-held, rock-solid, wide field observing, you can't beat the Canon image-stabilized binoculars we keep in stock.

Canon

Or it might be a Takahashi.


Takahashi FS-102UH (4" f/8 fluorite/SD on EM-10USD mount)

While many people swear *at* the long delivery times quoted by some manufacturers of premium refractors, most knowledgeable astronomers swear *by* the uncompromised optical quality and fast delivery of the Takahashi refractors we keep in stock.

From the 3.1" **FS-78** to the 5" **FS-128**, we stock Takahashi fluorite/special dispersion glass apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast*. Why wait for up to a year to observe through an apo refractor from another manufacturer? You can be usually be viewing through a truly fine Takahashi apo only a few short days after you order from us. We stock complete Takahashi scopes on USD mounts with dual-axis 50x sidereal slewing, as well as apochromatic optical tubes only to install on your own mount.

We also have the amazing Takahashi **FSQ-106** 4" dual fluorite lens 4-element f/5 apo refractor. It's both a visual scope and 4" focuser astrograph.

Also available from stock is the unique Takahashi **CN-212H** 8.3" reflector that converts from an f/12.4 classical Cassegrain reflector to a very fast f/3.9 Newtonian for visual observing and astrophotography.

If you want something bigger, 6" doublet and triplet apo optical tubes and complete scopes are available on a special order basis.

If you want an apo, and want it now, it's Takahashi from ***astronomics***.

It might be this $999 Celestron C5+.

Celestron 5" C5+, with optional hand control **$999**

We made a special purchase of 200 **Celestron C5+** scopes – with tripods – that lets us sell them for only $999. That's $300 below our regular price, and less than the normal dealer cost of the scope alone!

The C5+ has both a tabletop mount *and* adjustable height tripod, 25mm eyepiece (50x), 6 x 30mm finder, setting circles, manual slow motion controls, dust covers, and a 1.25" star diagonal. The optical tube detaches in seconds for use on your camera tripod as a spotting scope or telephoto lens.

The built-in DC drive runs up to 50 hours on a single 9-volt battery and becomes a dual axis drive corrector for astrophotography by simply adding an optional dec motor and hand control (also sale priced – at only $100 for both!)

Astronomy praised its "superb optics" and called the C5+ "an ideal telescope for many of today's buyers . . . an excellent value in an all purpose telescope." At our low sale price, it's a bargain as well!

> Thanks for producing an exceptional web site. While I was an avid skywatcher when I was in the fifth grade, I needed some brushing up, and your site was perfect. You gave clear and concise explanations and definitions that I can easily use with my students. After looking at three books trying to understand declination and right ascension, your definition made the concept click for me.
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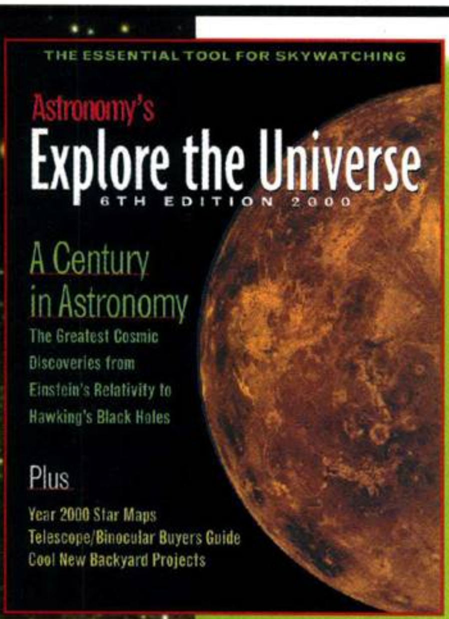
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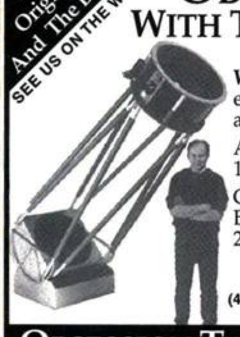

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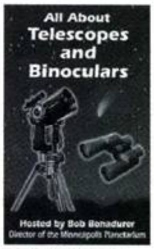
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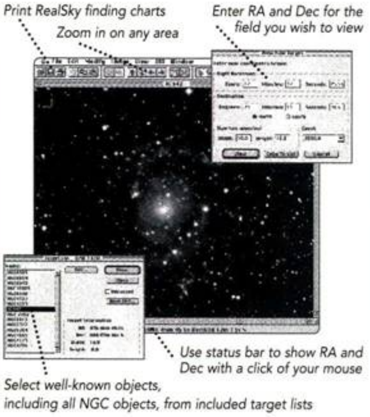
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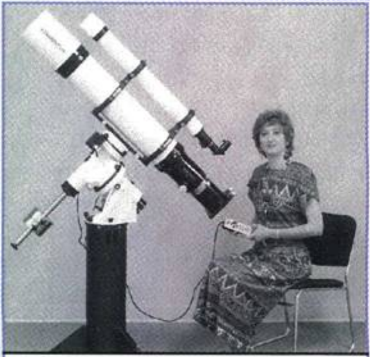

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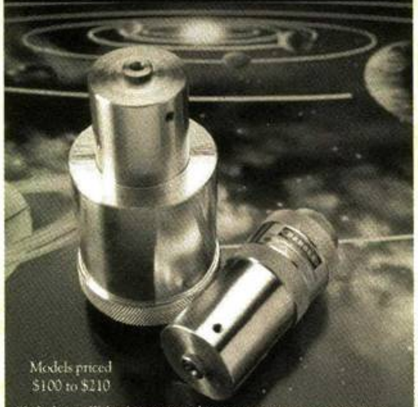

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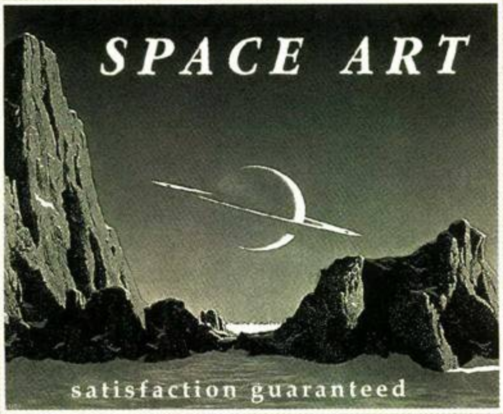

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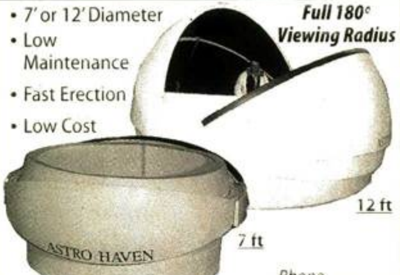

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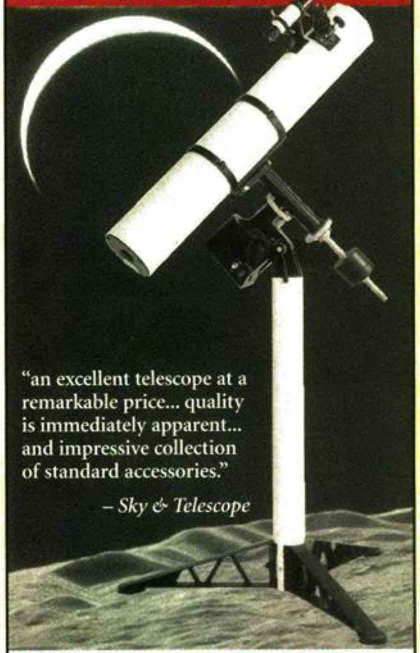

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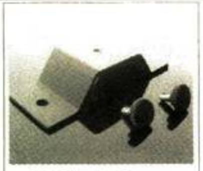

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OCTOBER

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Saturday evening's chuck-wagon dinner, Indian dancers, and twilight talk on Southwestern archaeoastronomy will put you in the mood for a night of observing under velvet-black skies.

For more information, contact The Enchanted Skies Star Party, P.O. Box 743, Socorro, NM 87801; (505) 835–0424; e-mail, chamber@socorro-nm.com; website, www.socorro-nm.com/starparty.html.

Paul Schwartz

The Enchanted Skies Star Party will begin with a behind-the-scenes tour of the National Science Foundation's Very Large Array radio telescope, made famous in the movie *Contact*.

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▶ The Montreal Museum of Fine Arts, Montreal, Quebec, Canada. Call (514) 285–2000; website, www.mbam.qc.ca/a-sommaire.html.

OCTOBER 1–2
Skyscrapers' Astro-Assembly

▶ Seagrave Memorial Observatory, North Scituate, Rhode Island. Contact Bob Napier, Seagrave Memorial Observatory, 47 Peeptoad Road, North Scituate, RI 02857; (401) 934–0980.

OCTOBER 1–3
Stella-Della-Valley

▶ Camp Onas, Ottsville, Pennsylvania. Contact Ed Radomski, 36 Far View Rd., Chalfont, PA 18914; (215) 822–8312.

OCTOBER 2
Astrophotography Presentation and Banquet

▶ Flamingo Hilton, Reno, Nevada. Featuring renowned astrophotographers Tony and Daphne Hallas. Hosted by the Astronomical Society of Nevada. For information, call (775) 329–8809.

OCTOBER 2–3
Victorian Amateur Astronomers' Conference

▶ Norwood House, Mount Martha, Victoria, Australia. Contact Richard Pollard, P.O. Box 596, Frankston, Victoria 3199; website, www.peninsula.starway.net.au/~aggro.

OCTOBER 4–10
Okie-Tex Star Party

▶ Camp Billy Joe, near Kenton, Oklahoma. Contact Okie-Tex Star Party, P.O. Box 128, Mustang, OK 73064; Steve Adkins, (405) 722–1678.

OCTOBER 5–9
Twin Lakes Star Party

▶ Golden Pond Observatory in the Land Between the Lakes National Recreational Center, Golden Pond, Kentucky. Contact Michael Nicholas, 234 West Jefferson Street, Paducah, KY 42001; e-mail, manldn@apex.net.

OCTOBER 7–10
Great Plains Star Party

▶ Scopeville, south of Osawatomie, Kansas. Contact Walt Robinson, 515 West Kump, Bonner Springs, KS 66012; (913) 422–1262.

OCTOBER 8–9
All-Arizona Star Party

▶ SilverBell Estate Ranches, near Arizona City, Arizona. Contact Diana Jane, (480) 833–2002.

OCTOBER 8–9
Dark Sky Camp Out

▶ Cathedral Gorge, Panaca, Nevada. Contact Jim Mellor, 2052 High Mesa Drive, Henderson, NV 89012; (702) 361–1356.

OCTOBER 8–10
Midwest Space Development Conference

▶ Lakeland Community College,

Kirtland, Ohio. Contact Annette Wood, (440) 353–0368; e-mail, AnnettesW@aol.com.

OCTOBER 8–10

South Jersey Star Party

▶ Belleplain State Forest, near Woodbine, New Jersey. Contact the South Jersey Astronomy Club, 681 Port Elizabeth-Cumberland Road, Millville, NJ 08332; Paul Ostwald, website, members.aol.com/sjastroc.

OCTOBER 9

Blue Ridge Parkway Regional Stargaze

▶ Julian Price Park, Blue Ridge Parkway, south of Blowing Rock, North Carolina. Contact Greg Kirby, 5026 Poplar View Lane, Granite Falls, NC 28630 (send a SASE); (828) 396–7656.

OCTOBER 9

North Texas Amateur Astronomers' Star Party

▶ Cleburne State Park, Cleburne, Texas. Contact Michael Hibbs, (817) 238–9883; website, members.aol.com/skywatchpr/home.html.

OCTOBER 16

Nova Star Party and Telescope Meet

▶ Crockett Park, south of Washington, D.C. Contact Jeff Cook, (703) 524–5333; website, www.cookstudios.com/nova.htm.

OCTOBER 20–23

Great Lakes Planetarium Association Conference

▶ Radisson Plaza Hotel, Kalamazoo, Michigan. Contact Eric Schreur, Kalamazoo Valley Museum, P.O. Box 4070, Kalamazoo, MI 49003; (616) 373–7978; website, www.pa.msu.edu/abrams/glpa.html.

OCTOBER 23

Free Public Star Party

▶ Ralph A. Worley Observatory, south of Shreveport, Louisiana. Contact Cran Lucas, (318) 797–1524; website, www.lsus.edu/nonprofit/sbas/.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com. Look for additional events at http://www.astronomy.com.

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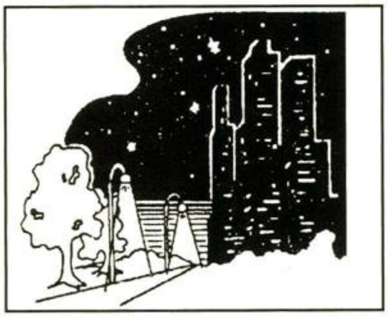

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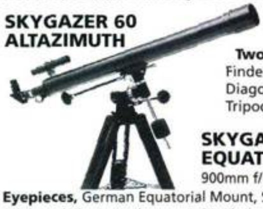

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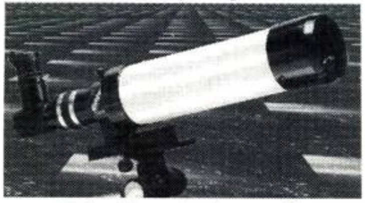

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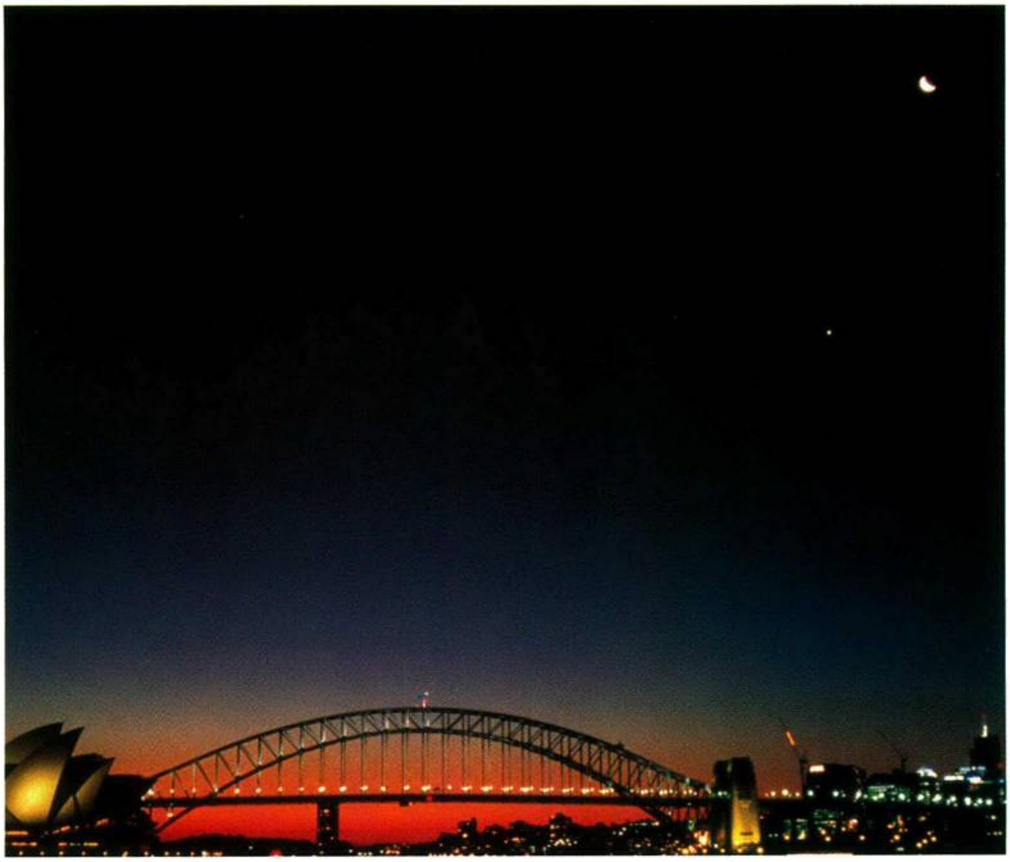
Jupiter Up in Flames

For the Fourth of July holiday in 1994 I drove to New Mexico to visit my family and take astrophotos for use in my classroom. On the road, I began making a mental list of the exact shots I would take. My plans would soon be changed. Ten miles before the Malpais State Park, I could see lights scattered in the Patos Mountains from forest fires. They appeared small and well-contained.

I stopped at a roadside picnic area to take some photos before driving on. The sky seemed perfectly clear, but there were no stars at all, not even bright Jupiter. The smoke particles from the forest fires were blocking stars from view.

The next day was the Fourth of July. It was the 50th anniversary of the rescue of Smokey the Bear, the little cub with burned paws saved from a forest fire here. Ironically, fires today were spreading in the mountains as we celebrated. At that hour, three major fires were burning in Lincoln County — in Baca Canyon, Arabela, and the Patos Mountains. Firefighters were usually able to call in reinforcements from surrounding areas, but a rash of forest and grass fires throughout the southwest prevented this.

That evening four of my family members and I went to the Patos Mountains to get a look at the fire with our cameras and regular



Night Falls Over Sydney

BRENDAN SISSON

(70mm lens at f/8, Fuji 100 film, 4-second exposure)

Galaxy NGC 5128

KEN AND MATT BLANKENSHIP

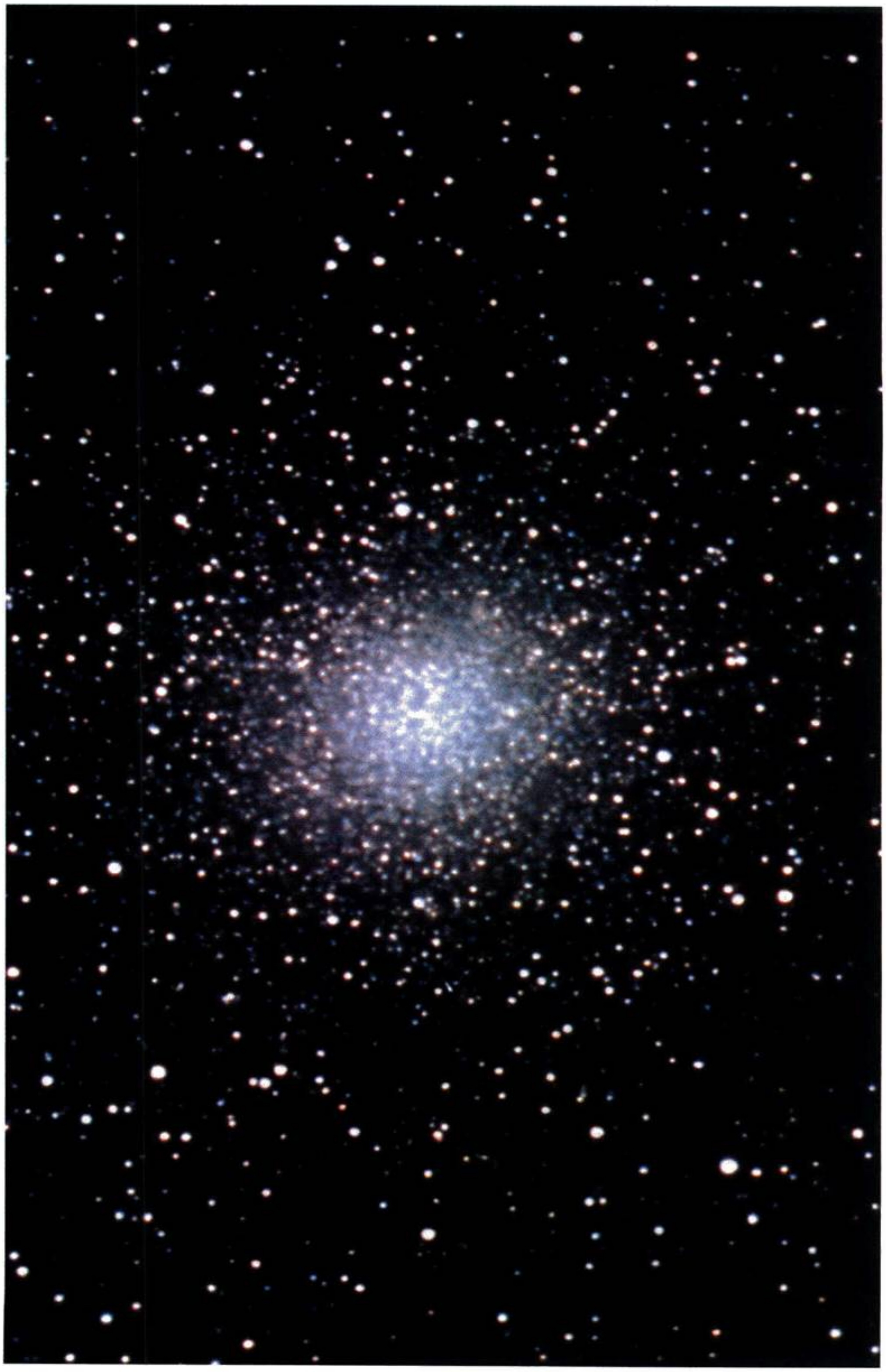
(14-inch at f/7.5 SCT, Kodak PJ-400 film, 45-minute exposure) and infrared binoculars. It was spectacular. Words cannot describe it. In fact, for long stretches of time we watched the fire and the night sky with few words between us . . . an unusual feat for five talkers.

Above the 100-foot flames and the glow of the fire was Jupiter in the south-southeastern sky. A few stars flickered in and out of view . . . Arcturus and others . . . but mostly there was Jupiter reigning above it all. Far to the right, following the ecliptic, was Venus at the western edge of the sky. Jupiter and Venus were so positioned that the forest fire raged between the two of them.

By the time Venus set, the firefighters were on the outskirts of the fire, working to keep it away from ranchers' homes and livestock. We watched several more hours as the fire raged methodically up the entire mountainside, working its way up and over the mountain ridge and down the other side. The trees, full of sap, exploded one by one as the fire grew hotter and progressed in slow motion up the mountain.

Jupiter, hovering just above the raging fire and exploding trees, was to have a similar succession of explosions on its surface in two weeks with the coming collision of Comet Shoemaker-Levy 9. The fiery explosions were a preview of things to come.

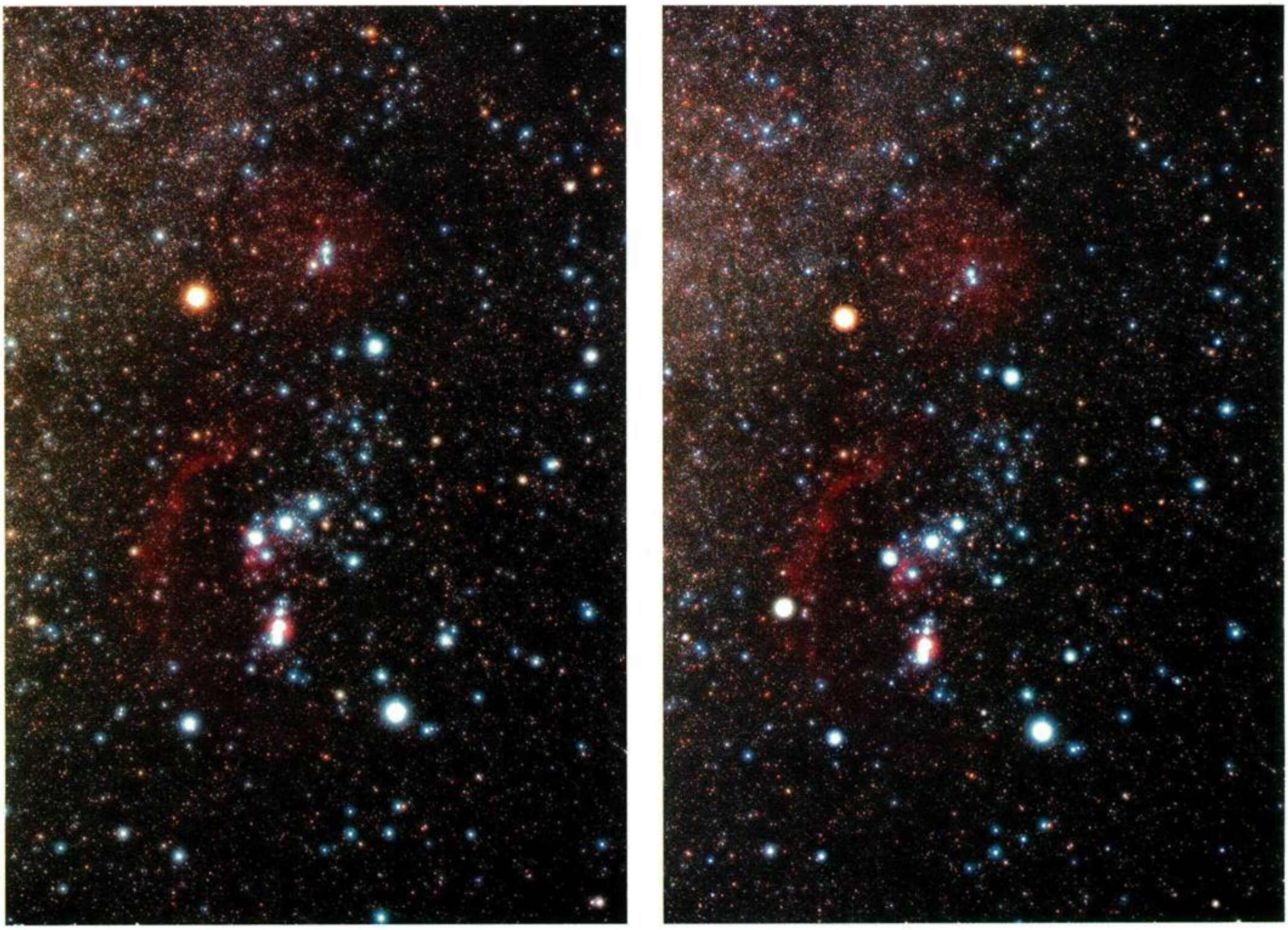
Surprisingly, behind us to the north, the constellations were shining in a calm sky. The winds were blowing strong to the south, carrying the smoke away in that direction. Our old friends — Cygnus, Ursa Major, Draco, Cepheus, and Cassiopeia — diverted our

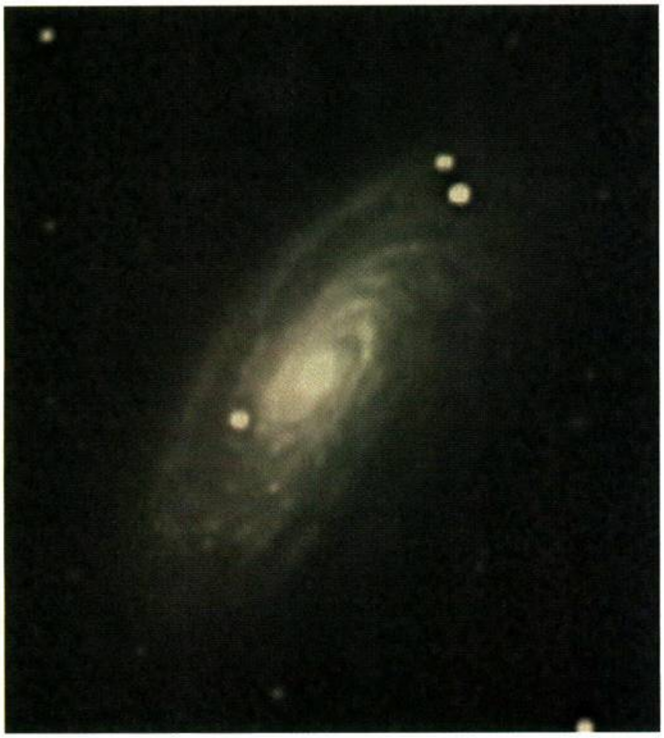


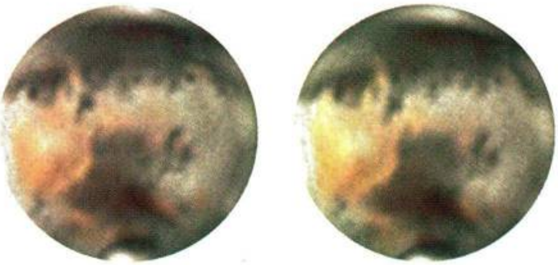
Globular Cluster Omega Centauri

MICHAEL J. AND LISA GRADY

(6-inch f/7 refractor, Kodak PPF 400 film, composite of two 45-minute exposures)







Orion as Seen from Earth and from Barnard's Star

AKIRA INAKA

(50mm lens at f/2.8, Kodak Gold 400 negative film, 19-minute exposure taken September 29, 1997; second image is rendering of what Orion would look like from Barnard's Star, note our sun at left)

Supernova 1999cl in M88 (Bottom left of galaxy core)

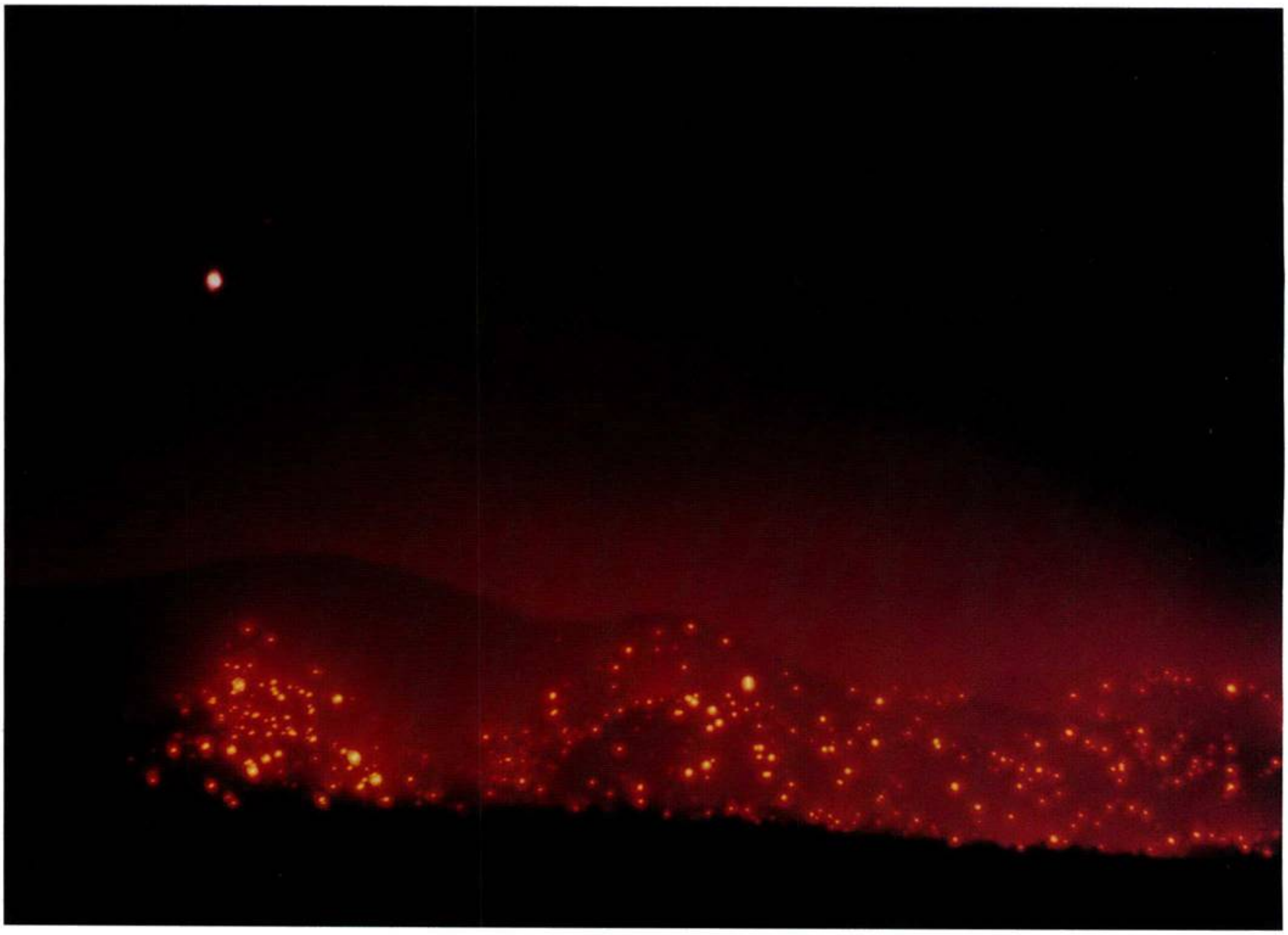
JEFFREY A. MACQUARRIE

(16-inch f/4.5 reflector, Cookbook CB245 CCD camera, integration of 63 15-second exposures taken June 4, 1999)

The Eye of Mars (Solis Lacus)

DONALD PARKER

(16-inch reflector at f/47.8, composite of 11.5-second blue, 4.75-second green, and 0.41-second red exposures taken May 14, 1999)

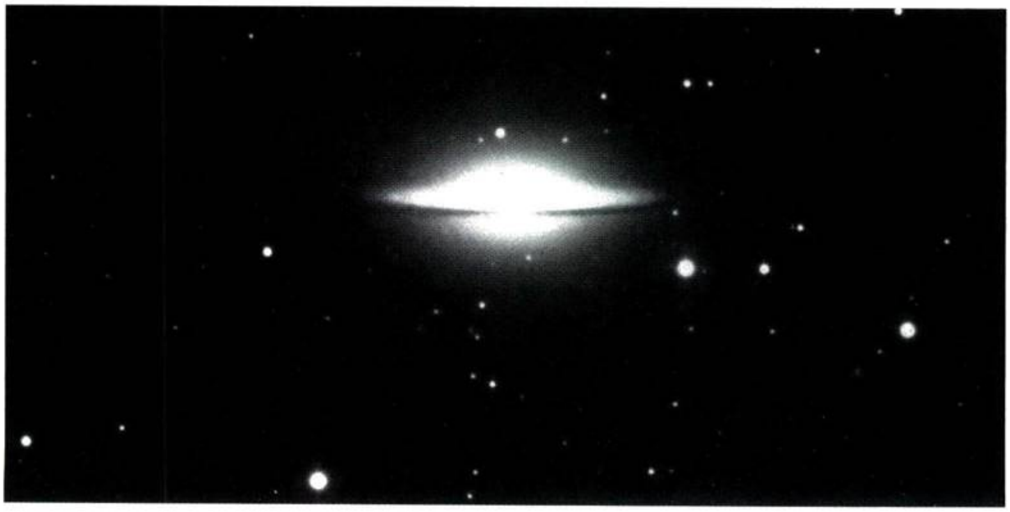


attention temporarily from Jupiter and the flames.

We finally left in the early hours of the next morning, our retinas fully saturated with the color red and still in awe.

In the years since then, I've had other opportunities to take the night-sky photos I originally planned for that New Mexico trip. But I will never again have the opportunity to photograph Jupiter above the burning Patos Mountains, awaiting its own disaster.

Sallie Teames, a middle school teacher in Fort Worth, Texas, is the founder of the Texas Society of Young Astronomers and a member of the Fort Worth Astronomical Society.



Jupiter and Forest Fire

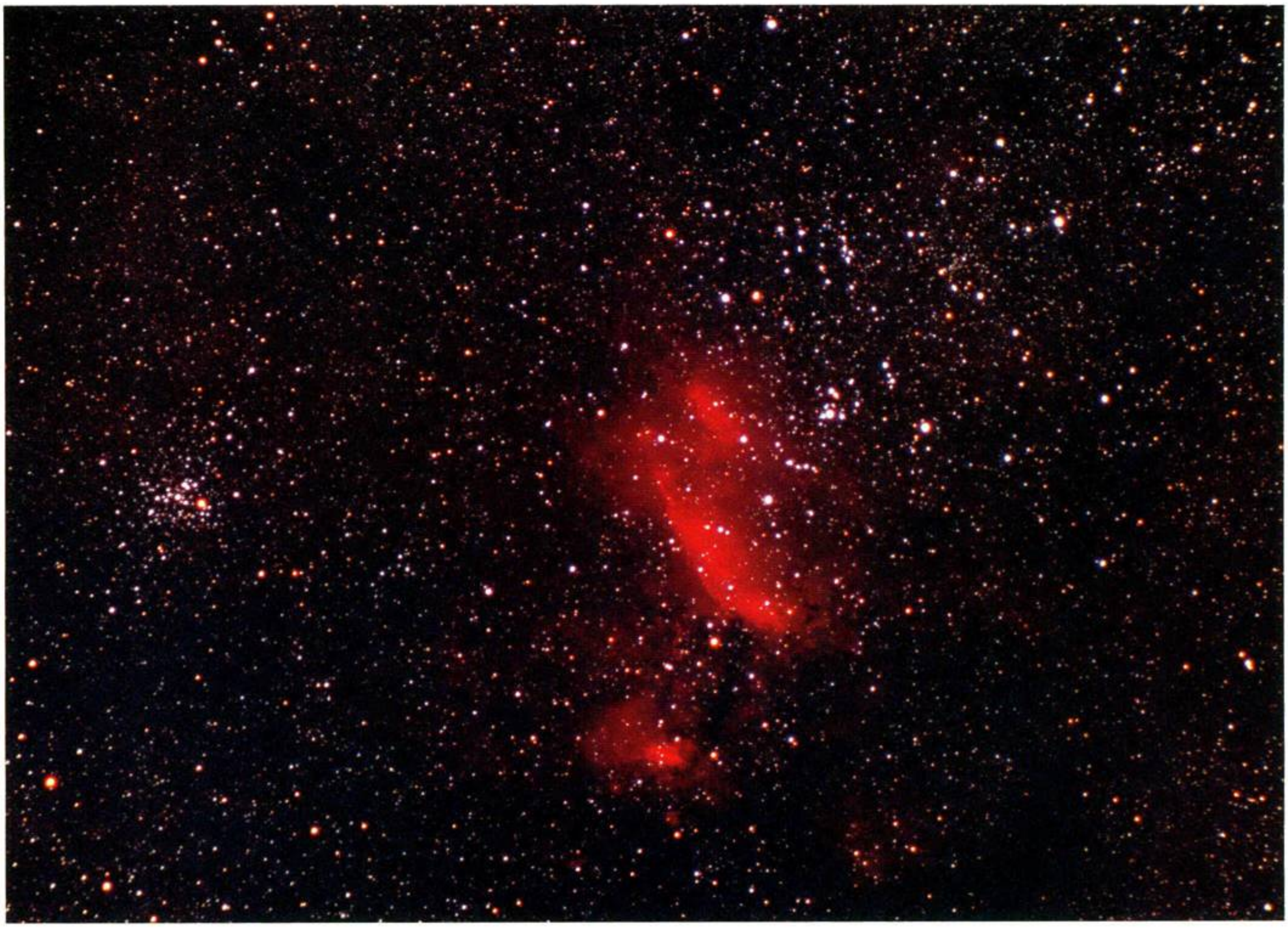
SALLIE TEAMES

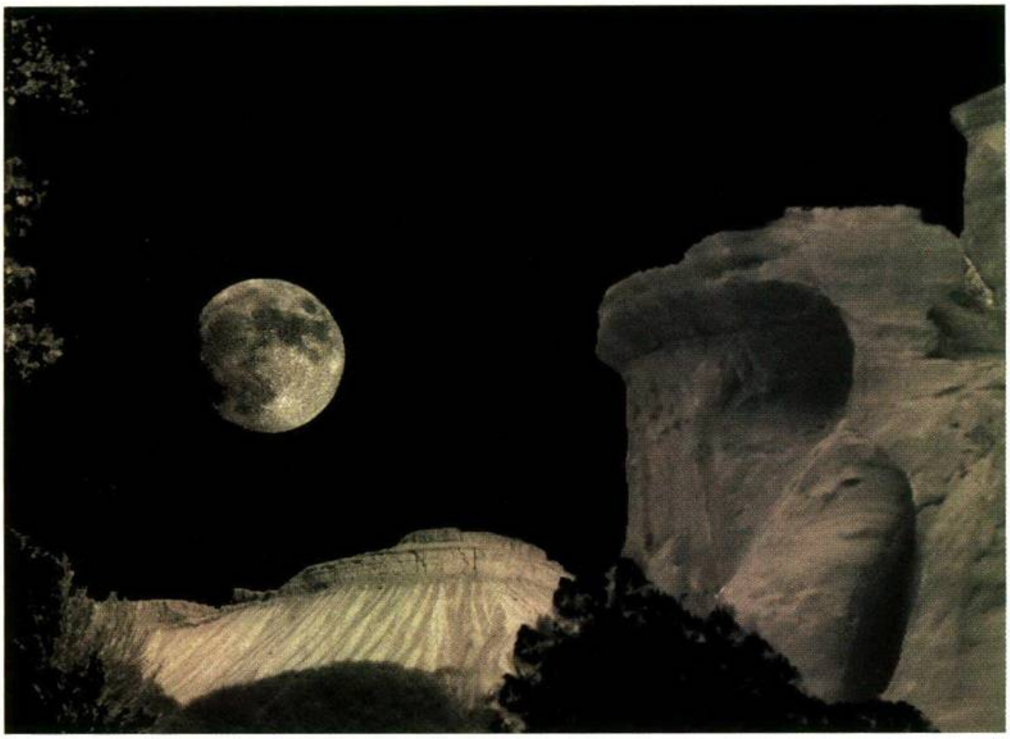
(28mm lens, Scotchcrome 400 film, 1-minute exposure taken July 4, 1994)

The Sombrero Galaxy (M104)

MARTIN C. GERMANO

(14.5-inch reflector at f/6, Kodak Hypered Technical Pan 2415 film, 85-minute exposure)





Emission Nebula IC 4628

CONRAD POPE

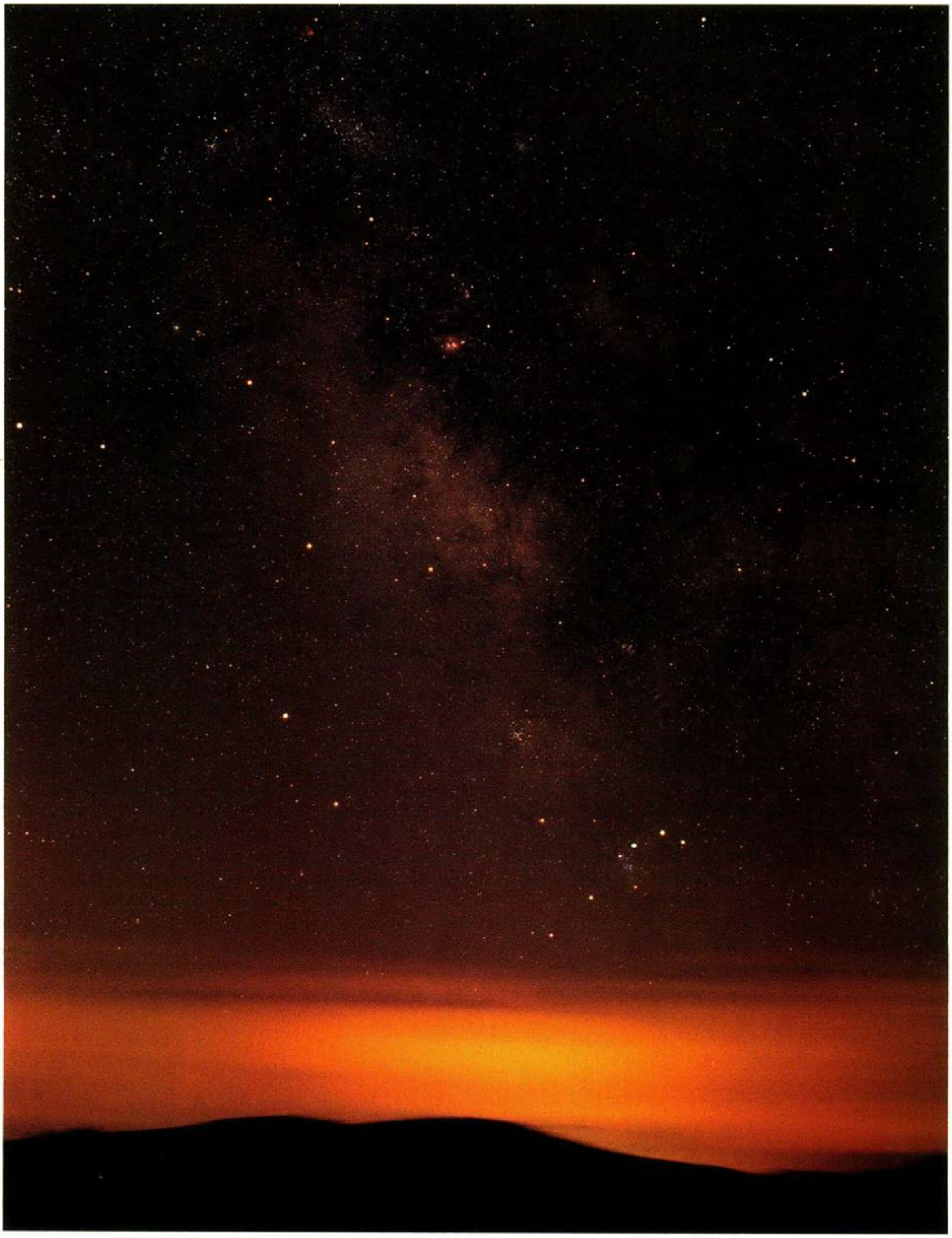
(94mm f/7 refractor, Kodak PJ400 film, composite of two 30-minute exposures)

Moon over Mt. Garfield

JACK HENIFORD

(210mm lens at f/16 [moon] and 50mm lens at f/11 [foreground], Kodacolor Gold 200 film, taken June 1998)

This month's best astrophoto



Milky Way Rises above Light Pollution

HENRY ORLIND

(50mm lens at f/2.8, Fuji 800 print film, 7-minute exposure taken July 25, 1998)

The Milky Way rises over light pollution near McGregor Observatory during the 1998 Stellafane convention.

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CCD image of globular cluster Omega Centauri. Taken with the Meade 16" LX200 Schmidt-Cassegrain telescope by Tim Puckett and Alex Richter at Johannesburg, South Africa. Exposure time: one minute.

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